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Investigation of the Thematic and Methodological Trends of Completed Graduate Theses Related to Mathematical Modeling in The Field of Mathematics Education[1]

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Abstract
The aim of the research is to determine the thematic and methodological trends of completed national and international master's and doctoral theses related to mathematical modeling in the field of mathematics education. Qualitative research method was used in the study, and a case study was adopted as a model. Within the scope of the research, from the master's and doctoral theses published in Turkish and English in the field of mathematics education and training covering the years 2013-2023 (October), in the YÖK National Thesis Center and in the ProQuest database; A total of 197 theses on mathematical modeling were examined with the Thesis Evaluation Form. Mendeley Reference Manager, SPSS Statistics 26 package program and VOSviewer program were used in the analysis of the data. Thematic analysis and content analysis, quotation analysis from bibliometric analysis and keyword analysis were performed. According to the results of the research; It is seen that there was a significant increase in theses related to mathematical modeling in mathematics education, especially in 2019, while the number of theses decreased in 2020 and 2021, and there was a significant increase again in 2022. It has been determined that the majority of studies on mathematical modeling in mathematics education in Turkey are at the master's level, while doctoral studies are more common in the USA and Canada. The university that produces the highest number of theses in the field in related researches is Atatürk University in Turkey and Columbia University abroad. Considering the distribution of the subjects of the researches; The most common issue was the development of modeling activities with 45 studies. When we look at the distribution of learning areas, the most studied area is the subject of "Numbers and Operations" with 58 theses. The most commonly used method is qualitative research with 61.42% and the most common model is case study with 59.39%. It was determined that the most common sample type used in the studies was secondary school students. Content analysis is the most commonly used type of analysis in theses, and GeoGebra is the most commonly used technology. In the context of these results, suggestions were presented to the stakeholders.

Keywords: Mathematical modeling, bibliometric analysis, mathematics education, modeling, technology

INTRODUCTION

Mathematical modeling in mathematics education has emerged as a research topic on which extensive research has been carried out in recent years. Mathematical modeling is proposed as a powerful tool, especially in mathematics, that allows us to understand concepts and processes expressed abstractly by associating them with real-world problems (Harrison, 2001). Mathematical modeling can enable students to see mathematics not only as a lesson, but also as a powerful tool that they can use to solve problems they encounter in their daily lives (Keskin, 2008).

It is a fact that extensive research is needed to understand the potential effects of mathematical modeling on student achievement, problem-solving abilities, and understanding of mathematics.

[1]This article is derived from the corresponding author's master's thesis titled Investigation of the Thematic and Methodological Trends of Completed Graduate Theses Related to Mathematical Modeling in the Field of Mathematics Education.

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For this reason, it is an undeniable need for researchers to reveal the point where the subject has evolved by identifying the deficiencies in the research, and on the basis of teachers, it is an undeniable need to systematically evaluate the effect of the mathematical modeling process on learning outcomes, student participation and motivation. In addition, how teachers implement these strategies in the classroom, how they adapt them to student needs, and the challenges they face in this process are among the topics that need to be covered widely. The aim of this study is to make thematic and methodological analyzes of master's and doctoral theses prepared in the field of mathematical modeling in Turkey and abroad within the framework of mathematics education and training, and to reveal the general status of the relevant modeling studies in this process.

Mathematical Modeling

Over the past two decades, mathematical modeling has been discussed by different researchers in the field of mathematics education, but the definition of mathematical modeling differs in different studies. Blum and Borromeo Ferri (2009) define mathematical modeling as "the process of translation between the real world and mathematics in both directions" (p. 45). According to this definition, the "real world" includes situations outside the world of mathematics, encompassing "nature, society, daily life, and other scientific disciplines" (Pollak, 2007). Carlson et al. (2016) define mathematical modeling as "a process in which mathematics is used to solve authentic, real-world problems."

According to Carreira and Baioa (2011), the result of the process by which students express, interpret, experiment, and stimulate their thoughts is called a mathematical model, and this process is known as mathematical modeling. According to Kertil (2008), mathematical modeling includes the conceptual structures necessary to mathematically understand the problem situations encountered. Keskin (2008) defines mathematical modeling as a process that overcomes real-life problems that require solutions; According to Kapur (1998), mathematical modeling is a process that allows both solving real-life problems and adapting mathematical problems to real-life situations. Erbaş et al. (2014) define mathematical modeling as the analysis of a real-life event by mathematical methods; Niss (1988) defined mathematical modeling as a combination of mathematical structures used to represent a specific part of a real-world situation and the relationships between these structures.

According to Blum and Borromeo Ferri (2009), the objectives of mathematical modeling are; (i) to assist students in understanding real-world phenomena; (ii) support all forms of mathematics learning, including motivation, comprehension, and concept formation; (iii) to improve mathematics proficiency and (iv) to gain a more accurate and descriptive mind in order to present a mathematical perspective. The term mathematical modeling can sometimes be confused with modeling mathematics, but mathematical modeling differs from the understanding of modeling mathematics, which is done to comprehend the abstract structure of mathematics (Çavuş-Erdem, 2018). For example, concrete materials such as decimal counting blocks, algebra tiles, and fraction cards are tools used to make mathematical concepts and operations more understandable. Therefore, mathematical modeling is often perceived as the use of concrete materials at the elementary school level (Lesh et al., 2003). Cirillo et al. (2016), on the other hand, consider the representation of mathematical concepts and structures with visual representations, which is defined as modeling in mathematics, and considers it as a separate concept from mathematical modeling. The main goal in modeling mathematics is to make mathematical concepts understandable in a visual form, but the goal in mathematical modeling is to develop conceptual tools that can be solutions to real-life problems. In the process of mathematical modeling, in addition to visual and concrete models, various structures such as equations, inequalities, graphs, and tables can also be models.

Mathematical Modeling Process

Research on mathematical modeling shows that the modeling process is cyclical. In this context, the researchers have tried to determine the process that should be applied to provide students

with mathematical modeling skills by examining the mathematical modeling steps, the relationships and transitions between these steps. Studies show that mathematical modeling is a comprehensive and complex process (Justi and Gilbert, 2002).

Blum and Leiß (2007), who describe the mathematical modeling process, describe this process with a particular focus on the state model stage. The first step in the modeling process is to understand a real-life situation or problem and create a mental representation of it. When moving on to the real model or problem through this representation, the situation is simplified, structured and the necessary elements for the solution are determined using mathematical information (Blum and Leiß, 2007). After the real model or problem is created, mathematization is carried out with the help of mathematical information and thus a mathematical model or problem emerges. By using modeling skills, solutions to these mathematical models or problems are obtained and results are reached. Mathematical results are compared with their real-world counterparts and these results are interpreted. Finally, the concordance between real-world results and mental representations is evaluated, and the verification process is completed (Borromeo Ferri, 2006; Blum and Leiß, 2007).

Mathematical Modeling Approaches

There are different approaches to mathematical modeling and there is no universal understanding (Kaiser and Sriraman, 2006). While some researchers (Lesh and Doerr, 2003) adopt mathematical modeling as a paradigm beyond structuralism, seeing it as a new approach in education and training; others perceive mathematical modeling as expressing real-life situations of prepared mathematical structures, models, and formulas in mathematical language, including real-life applications (Haines and Crouch, 2007).

As a result of their efforts to classify modeling studies in congresses organized by ICMI (International Commission on Mathematical Instruction) and ICTMA (The International Community of Teachers of Mathematical Modelling and Applications), three main perspectives on general objectives and theoretical frameworks were identified by Kaiser and Sriraman (2006);

i. *Pragmatic perspective:* This approach focuses on pragmatic goals, using mathematics to solve practical problems in everyday life.
ii. *Scientific-humanitarian perspective:* This approach aims to develop students' ability to make connections between mathematics and reality, with an emphasis on science and humanistic education.
iii. *Holistic perspective:* This approach defines the modeling process in a common framework of scientific, mathematical, and pragmatic objectives.

A striking classification of mathematical modeling in the literature is the classification that includes four basic different approaches put forward by Berry and Houston (1995). These approaches can be listed as experimental modeling, theoretical modeling, dimensional analysis modeling and simulation modeling.

i. *Experimental Modeling:* This type of modeling is carried out in such a way that the process creates graphics or parity as a result. A model is created by solving the problem with the use of experimental data. Experimental modeling solves practical problems through the use of hard data.
ii. *Theoretical Modeling: It is* a type of modeling created by basing the formula obtained at the end of the process on theoretical foundations. The problem-solving process is based on theory as well as data.
iii. *Dimensional Analysis Modeling: It* is the modeling obtained based on the concept of dimension in the field of physics. In fields such as engineering and science, this type of modeling is created by grouping variables in an appropriate way.

iv. *Simulation Modeling:* This form of modeling is created by simulating the available data with the help of a computer. Computers are often used to create abstract models and evaluate unattainable probabilities.

Furthermore, other approaches cited by Kaiser and Sriraman (2006) are as follows:

i. The realistic or applied modeling approach aims to develop students' problem-solving and modeling skills, comparing them to problem situations from engineering and other disciplines and encouraging them to apply mathematical knowledge in different contexts.

ii. The educational modeling approach, as a blend of realistic and contextual modeling, uses mathematical modeling to create appropriate learning environments and processes to teach students concepts.

iii. The epistemological or theoretical modeling approach focuses on the relationships between math concepts and students, drawing attention to each step of the problem-solving process and placing less emphasis on the importance of realistic context.

iv. The cognitive modeling approach analyzes students' cognitive and metacognitive thought processes during the modeling process and provides teachers with an environment that guides them to understand and support students' thought processes.

v. The contextual modeling approach emphasizes the necessity of combining often more than one discipline, topic, or major theory to create realistic complex decision-making situations, justifying the philosophy that knowledge is organized around experience.

According to Galbraith and Stillman (2006), there are 3 different approaches in the field of modeling. These can be summarized as follows;

i. The "general application approach" focuses on a specific application. Typically, the teacher introduces the model and students use the model in a controlled way. This approach is often used in secondary schools and includes step 4 (calculating, solving inequalities, etc.) and step 5 (interpreting and verifying actual results in everyday life) of the modeling process.

ii. The "structure modeling approach" uses real-life situations and covers all stages of the modeling process from step 1 (the student's understanding of the problem situation) to step 7 (presenting possible solutions to the problem). The teacher makes a significant effort to understand the mathematical model used in stage 3 (the process of mathematization).

iii. "Open modeling approach". In this approach, students work with the given problems with the limited help of the teacher, because the teacher does not have to control the students. This approach is not widely used

Mathematical modeling is divided into modeling as an end *and* modeling as a means *with an alternative approach* (Galbraith, 2012). In the *modeling-as-purpose* approach, the focus is on the development of the skills and competencies necessary to model real-life situations. In contrast, the *modeling-as-tool* approach emphasizes the use of models in teaching mathematical concepts. In the perspective of *modeling as a purpose*, mathematics is taught using existing models, while at the same time, it is aimed to develop students' modeling skills by solving real-life problems with the help of these models. In the *modeling approach as a tool*, the main purpose is to teach mathematical concepts and mathematical modeling method is used for this purpose. This type of modeling approach allows for the learning of mathematical concepts based on the needs of real life. Thus, students participate naturally in the activities and take an active role in the process (Dost, 2019).

Purpose and Importance of the Research

The aim of this research is to determine the thematic and methodological tendencies of national and international master's and doctoral theses related to mathematical modeling in the field of mathematics education. In this context, answers to the following research questions were sought;

A. What are the distribution and changes of the thematic features of master's and doctoral theses on mathematical modeling by years?
   - What is the distribution of theses by year?
   - What is the distribution of theses according to the countries where they are made in terms of type?
   - What is the distribution of theses according to the universities where they are made?
   - What is the distribution and change of thesis topics over the years?
   - What are the distribution and changes of the learning areas of the theses over the years?

B. What are the distribution and changes of the methodological features of master's and doctoral theses on mathematical modeling over the years?
   - What are the distribution and changes of the methods in the theses according to the years?
   - What are the distribution and changes of the sample types in the theses according to the years?
   - What is the sample distribution according to the teaching levels where the theses are concentrated?
   - What is the distribution of theses according to sample group size?
   - What is the distribution of theses according to data collection tools?
   - What is the distribution of theses according to the data analysis used?
   - What are the distributions of technology use in mathematical modeling activities in theses?

Scientific research results have an important place in influencing various fields of science, policies and practices. These results both provide an empirical basis for practices and guide practitioners in professional activities. In addition, many studies in the field of education have found application by forming the basis of educational reforms. The approach of integrating the results of scientific research, examining research on a particular topic from a broad perspective, and creating a new product is one of the widely used research methods today.

Research such as determining the quality of educational research, mapping the general profile, the dimensions in which these researches evolved, and obtaining new upper results from the data (case study, systematic review, meta-analysis, etc.), which were especially popular in the United States in the 1980s, are among the types of research that have been widely covered in our country with the increasing accumulation in the 2000s. The first source to be determined by a researcher who plans to start new research is the studies that reveal the existing research, identify the missing areas in the literature, and present the results in a broad framework. Identifying trends by bringing together different studies in a particular area can help educators and decision-makers make informed decisions. It can also contribute to identifying potential strategies to improve teachers' practice in mathematical modeling.

When we look at the studies on the subject; Ünlü (2023), Eryiğit (2022), Koç (2020) and Albayrak (2017) have researches prepared at the graduate thesis level. The articles and theses in the literature have been meticulously examined, and the scope and limitations of these studies have been revealed. In this way, original research has been planned to fill the gap in the field. In the research of Eryiğit (2022); limited the research years to the years 2000-2020 and limited it only to the theses within the scope of the YÖK Thesis Center. In addition, he limited his research to theses made only at the primary education level. In this study, which was prepared in this context, the theses prepared in 2023 and the theses at different levels in the field of mathematics

education and training were included in the sampling and the gap was tried to be filled. Albayrak (2017) limited his study to theses up to 2016. Therefore, this study was limited to a total of 28 theses. Considering that modeling studies have intensified in recent years, this is a serious limitation for the current field. In our research, the study period has been extended to cover the years 2013-2023.

Koç (2020) limited his study to 2019 and did not engage in methodological analysis. In addition, the database was again limited to domestic markets. Therefore, bibliographic data is also out of the question. In this study, in addition to 4 years of current studies, method analysis, analysis of prominent themes and bibliometric data were also included. For this reason, our research was included in the theses in the ProQuest database, and research proposals, detailed method analysis and country information were also included. Since Ünlü (2023) limited the scope of the studies he sampled in his study in terms of success and attitude, there was no subject limitation in our study. In addition, since the thesis is a meta-analysis study, the method analysis was limited. First, this research will allow us to understand the current state of mathematical modeling in graduate-level academic studies. The thematic review of the theses helps us to determine which topics mathematical modeling is concentrated on and in which areas further research is needed. In addition, methodological analysis will shed light on the application of different methods by identifying the research methods used in studies on mathematical modeling. It is thought that this study will contribute to the field by guiding future researchers in understanding which methodologies are more effective and by drawing a methodological route for research in this field.

METHOD

Model of the Research

This research was designed with qualitative methods. Qualitative research is a method used to obtain new information or to add different perspectives to existing information in cases where complete information is not available or it is difficult to evaluate with quantitative measurements (Strauss and Corbin, 2007). Within the scope of the research, from the master's and doctoral theses published in Turkish and English in the field of mathematics education and training covering the years 2013-2023 (October), in the YÖK National Thesis Center and in the ProQuest database; Theses on mathematical modeling were examined. For this reason, a case study, one of the qualitative research types, was used as a research model. According to McMillan (2000), a case study is a method in which a specific event, environment, program, social group, or associated systems is studied in depth. Case study refers to an in-depth process of analysis and identification on a finite system (Merriam, 2009). Yin (2009), on the other hand, defines a case study as 'a model that investigates a current event or phenomenon in its own environment'. Research; It aims to analyze different studies in the existing literature and to present a general perspective on the research topic.

Universe and Sample of the Research

Databases

In the research, one of the titles Sample, Study Group or Participants should be used according to the way the group is formed. Information on who the study group of the research consists of and the sampling method is stated in this section.

The study population of the research is the theses carried out in the field of mathematics education/training and on mathematical modeling. In the research, sampling was made in terms of databases, primarily *limited to YÖK National Thesis Center* and *ProQuest Dissertations and Theses databases*.

ProQuest Dissertations and Theses is a comprehensive database that provides access to master's and doctoral studies from academic institutions around the world. With records dating back to the 17th century, it is both historically significant and provides access to modern research. This database specifically covers dissertations made at institutions in the U.S. and Canada, but it also

has a wide range across the globe. Some records contain only abstracts or citations, but full-text versions are available through library services or by direct purchase. Users can search by criteria such as keyword, author, institution, subject, or date. Advanced search options allow for more specific queries with filters such as document type or language (ProQuest, 2024). *YÖK National Thesis Center is* a database where theses (master's, doctorate, medical specialization and proficiency in art) made in the field of graduate education in Turkey are archived and made available in digital environment. It was founded in 1987 and compiles academic studies conducted in universities in Turkey and makes them available to researchers. The database is one of the most comprehensive sources where graduate theses are collected, and since 2006, the digitalization process has accelerated and many theses have become accessible in the digital environment (Anonymous, 2024). Publications that are included in the research process and make up the sample; From master's and doctoral theses covering the years 2013-2023 (October), published in Turkish and English in the field of mathematics education/training, *in the YÖK Thesis Center* and in the *ProQuest Dissertations and Theses* database, the full text of which can be accessed (open to access); These are theses on mathematical modeling. *197 theses,* 144 in the *YÖK Thesis Center and 53 in the* ProQuest Dissertations and Theses database (*See.* Figure 3.1.) It was included in the research. These theses cover a total of 10,871 participants and 654 studies.

Screening strategy and inclusion/exclusion criteria

Scans made in the YÖK Thesis database

(i) The database was searched on 29.10.2023.

(ii) As the first scanning method*, the keywords "*mathematics*" and "*model"*, the search type "*in pass"*, the year "*2013-2023" were scanned in the titles and abstract in the database by using *the "in advanced scanning"* feature. As a result of this scan, 654 results were obtained. This file was transferred to *Excell*, the irrelevant titles were eliminated and the remaining titles *were written in the "Decision"* section as *"Those suitable for the purpose of the research"*. The first data pool was created with the remaining 137 studies.

(iii) In addition, using the *"Detailed Scanning"* feature as the second scanning method, the words "*Mathematical Modeling"* and "*Mathematical Model"* were written, and 843 studies were listed. With the 2013-2023 limitation, 578 studies remained on the list and theses in different disciplines were determined on this list. At this stage, color coding was applied and the theses that needed to be removed were indicated in red, and the theses that needed abstract scanning were marked in yellow. A separate file was created for the remaining theses as a result of the detailed title and abstract reading and the elimination. These theses were *transferred to the Excell* file. A data pool was created with the remaining 139 studies.

(iv) All theses obtained in the first and second methods were ranked and compared from small to large based on their thesis numbers, and the *missing theses of both methods were completed in the "Comparison" file and the overlaps were eliminated, and a total of 144 theses were transferred to the Mendeley program as full text and made ready for analysis.*

Search on the ProQuest Dissertations and Theses database

(i) The database was searched on 29.10.2023.

(ii) Different combinations of keywords and Boolean operators were used while scanning. In the examination, *due to* the use of the word *"modeling" in the form of* "modelling" in some of the foreign publications, the *keywords "*mathematical modeling" *were coded in the form of* math * model * *while scanning the* ProQuest Dissertations and Theses database.

(iii) In the ProQuest Dissertations and Theses database, a search was performed using different combinations with the keyword mathematical modeling. The keyword specified

in the search section of the database *is written as TI, AB (*"mathematical model*") to include *the "title and "abstracts" of the theses* . Since the requested scan contains an abbreviation character (*), the database scan is changed to TI, AB (("*mathematical model*" OR "*mathematical modeling*" OR "*mathematical modelling*" OR" *mathematical models*"")) and the screening was carried out with the "*include all*" housing of these suggestions. The year range of the studies is 2013-2023, the subject *is "mathematics education",* the publication language is filtered as Turkish and English. As a result of the screening, 65 theses were listed. This list was reduced to 60 theses when the full-text filter was added. 5 theses that are in Turkish and included in the YÖK Thesis Review have been removed from the list. In this case, 2 full texts, which were created and understood to be related to different disciplines in the title review, were removed from the list at this stage. Finally, the .ris file covering 53 theses *was introduced to the Mendeley* program, and was prepared for the data collection process.

Reasons why theses are not included in the scope of research:

(i) Not available in relevant databases

(ii) The full text is not accessible

(iii) There is no scientific research of the type designated as a report, etc.

(iv) Does not cover the subject of mathematical modeling

(v) It has not been done in the field of mathematics education/training

The PRISMA diagram *for the studies included* in the study is presented in Figure 1.

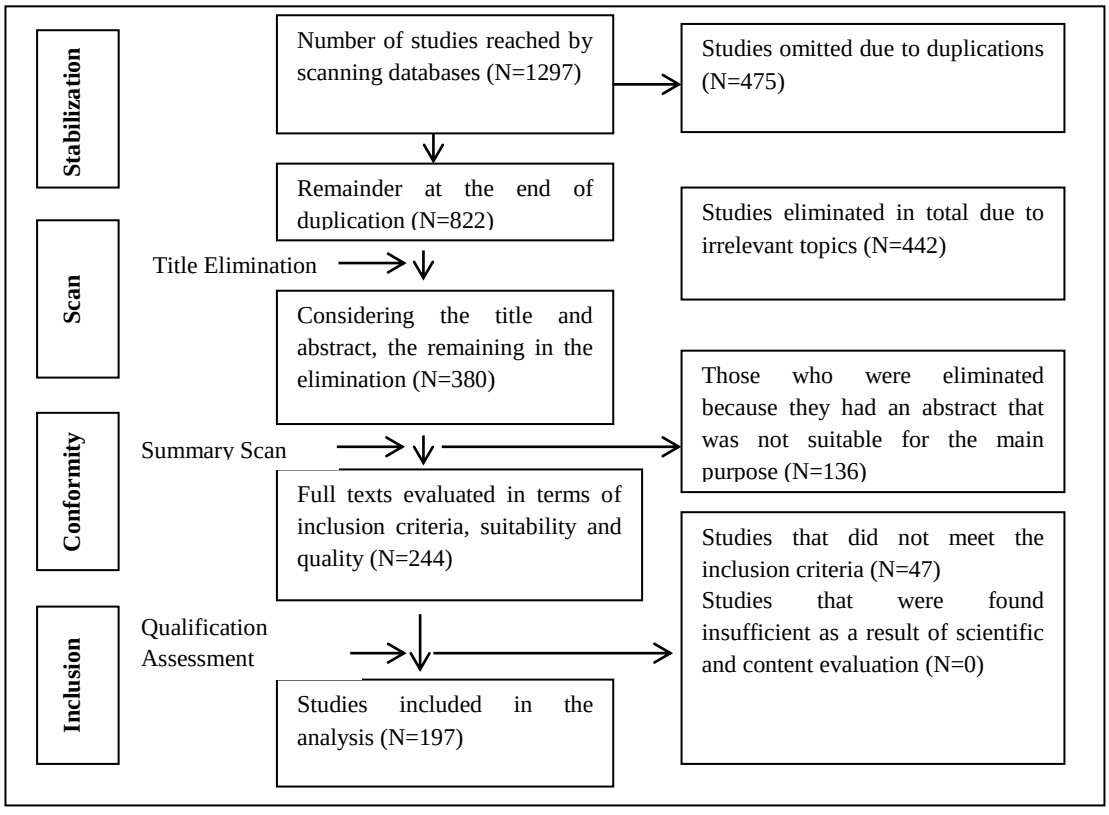


Figure 1. Flow diagram of the studies included in the analysis

As can be seen in the PRISMA diagram in Figure 1, all studies for mathematical modeling were first scanned in the relevant databases in order to determine the studies suitable for analysis. There were 1297 theses in the first study pool. Of the studies examined, 475 studies that were in duplication/overlap status were excluded from the scope. In the second stage, the remaining

822 studies were examined in depth, and 442 of these studies were not suitable for the study due to unrelated topics It has been removed from the pool on the grounds. As a result of the title and abstract elimination, the remaining 380 studies were subjected to detailed examination again and 136 theses were removed because they were not suitable for the purpose. 47 studies were excluded from the analysis on the grounds that they did not meet the inclusion criteria (carried out in different disciplines, etc.). Finally, the remaining 197 studies were transferred to the Mendeley Program for evaluation as they were fit for purpose.

Data Collection Tool

Using the Thesis Evaluation Form *presented in Annex 1*, each study was numbered and the relevant information was withdrawn from the theses. Research; The Thesis Evaluation Form, which was originally developed by Albayrak and Çiltaş (2017) and classified by Eryiğit (2022) in terms of mathematical modeling theses, was rearranged within the scope of research purpose and sub-objectives. The sections "preparation of modeling problems", "application period" and "categorization of mathematical modeling" in the *classification form of Eryiğit (2022)* were removed in the context of the purposes of the research and in line with the expert opinion*, "database", "publication language", "country where the thesis was conducted", "thesis advisor information", "university where the research was conducted", "keywords", "type of technology used",* and *"Number of Modeling Events"* sections have been added. The final form of this form, which is used for each thesis, belongs to the theses; *"Thesis Tag", "Country", "Publication Language", "Advisor", "Keywords", "Mathematical Modeling Topic", "Learning Area", "Research Method", "Research Model", "Research Design", "Data Collection Tool", "Data Analysis Tool Type", "Data Analysis Type", "Data Analysis Method", "Number of Samples", "Sample Type", "Sample Group Level", "Class Information Examined", "Type of Technology Used"* and *"Number of Modeling Activities"* information were withdrawn from the theses.

Analysis of Data

Qualitative analysis methods were used in the analysis of the data obtained. Since theses are valuable resources that provide information in the relevant field, it is known that researchers often work on these written materials in qualitative research (Wallen and Fraenkel, 2000). According to Cohen, Manion and Morrison (2007), documents; journals, technical documents, field notes, diaries, biographies and autobiographies, official records, papers, reports or statistics, primary or secondary sources, historical events or chronologies, photographs, projects, books, theses, plans, letters, articles. In this context, document analysis method was used in the research.

In the study, the analysis of the data was carried out in several stages. These;

(i) The theses in the study group were obtained from databases and transferred to *the Mendeley* program in computer environment.

(ii) In the second stage, *the analysis of the studies transferred to the Mendeley Reference Manager* program in order of code number *was carried out using* the Thesis Evaluation Form developed within the scope of the research.

(iii) As stated by Labuschagne (2003), content analysis is generally preferred in document analysis and the information in documents is categorized and classified. In this study, content analysis was used as the main method for data analysis. Content analysis is defined as the process of categorizing or coding specific words in a text by organizing them in a systematic way. In addition, emphasizes that content analysis is widely used in determining frequency with certain categories, especially through document reviews. In this context, the data were evaluated using categorical analysis and frequency analysis, which are content analysis types. (Dinçer, 2018; Büyüköztürk et al., 2019;mCohen et al., 2000).

(iv) First, frequency analysis was used, which focuses on counting the frequencies of message elements. In this type of analysis, countable units are determined and analysis indicators

are expressed as frequency. Frequency analysis reveals in a simple way the frequency of quantitative appearance of recording units. During the analysis, it was aimed to count the message elements according to the frequency of a particular element, and these counts were expressed as frequencies. This technique allows to understand how often a particular item occurs and the intensity and importance of this element in the context of analysis. As a result of frequency analysis, items can be classified in order of importance and grouped according to their frequency (Köhler and Stemmler, 1997). In this process , *SPSS Statistics 26* package program was used.

(v) In bibliometric analysis, which is another technique used in the research; The data were analyzed *with the help of the* VOSviewer program in *the common citation analysis* and *keyword analysis* stages. Bibliometric analysis is a method that examines the publications in the scientific literature and the characteristics of these publications. This type of analysis is used to evaluate research trends, scientific productivity, the most used sources, and interdisciplinary relationships. Bibliometric analysis, by evaluating the current situation in the literature, can guide future research and help us monitor the development of a particular field (Karataş, 2015). Bibliometric analysis is used for different purposes in research. According to Donthu et al. (2021), these are;

a) *Examining Publications:* Bibliometric analysis examines publications related to a particular subject, discipline or research area and allows you to follow the developments in that field. These publications usually include articles, dissertations, books, and conference proceedings.

b) *Author Analysis:* Author analysis aims to identify the authors who have published the most on a particular topic. In this way, prominent experts in the field and their work can be better understood.

c) *Journal Analysis: Determining* which journals receive more publications on a particular topic is part of bibliometric analysis. This can help us understand which journals are more research-intensive and the level of influence of those journals in the field.

d) *Citation Analysis: Citations* made by a study are considered an important indicator of the academic impact of that study. In bibliometric analysis, citation analysis is used to determine which works are referenced by others and how often.

e) *Co-citation Analysis:* This type of analysis examines the frequency with which two specific studies are cited together by the same other studies. This can help us identify thematic connections and interactions between different studies.

f) *Keyword Analysis:* Bibliometric analysis helps us understand research trends by identifying the most frequently used keywords related to a particular topic or field.

In this study, Bibliometric analyzes such as *Publication Review, Citation Analysis* and *Keyword Analysis* were performed.

Validity and reliability of the research

Validity in qualitative research means the ability of the researcher to observe the subject he is examining accurately and impartially. In addition, the researcher's explanation of the data collection process, the methods of reaching the findings and the detailed reporting of the obtained data are among the important elements to ensure validity (Yıldırım and Şimşek, 2008). In qualitative research, validity is divided into two main categories: internal validity and external validity. Internal validity is related to how accurately the research process reflects the phenomenon under study. In this respect, it is of great importance for the researcher to show consistency in data collection, analysis and interpretation processes (Büyüköztürk et al., 2008). In this study, the findings were explained in detail in order to ensure internal validity, the information about the research subject was supported by objective data, and then interpretations were made. In order to ensure consistency between the data, attention has been

paid to the criteria of internal homogeneity and external heterogeneity, so that similarities and differences are clearly revealed. External validity, on the other hand, means the generalizability of research findings. If the results of the research can be reproduced in similar environments and conditions, this indicates that external validity has been achieved. In this study, the process of extracting data from databases is explained in detail and the raw data are presented as publication information, although they are not presented as additional in terms of scope size.

Reliability refers to the transparent and detailed disclosure of the processes and data of the research; In other words, it allows another researcher to evaluate the study. In other words, it is about the reproducibility of research results (Yıldırım and Şimşek, 2008). In this context, the analysis of the data was carried out by two researchers and the formula of Miles and Huberman (1994) was used to calculate the reliability of the research. As a result of the calculation, the reliability of the research was found to be 87%. Values above 70% in reliability calculations indicate that the research is reliable. According to these results, it can be stated that the study is reliable.

RESULTS and DISCUSSION

In this section, four research questions determined within the framework of the research problem and sub-questions are taken into account and the findings obtained as a result of the data analysis are presented.

Findings and Discussion on the First Sub-Research Question

The analysis of the thematic features of the master's and doctoral theses related to mathematical modeling prepared in the field of mathematics education was carried out within the scope of the first research question. In this context, the findings of the distribution of national and international master's and doctoral theses related to mathematical modeling prepared in the field of mathematics education by years are presented in Table 1.

Table 1. Distribution of theses on mathematical modeling by years

Variable	Year	Database	*f*	%	*F* (Total)	% (Total)
Distribution by Years	2013	YÖK Thesis	3	1,52	10	5,08
		ProQuest	7	3,55		
	2014	YÖK Thesis	10	5,08	15	7,61
		ProQuest	5	2,54		
	2015	YÖK Thesis	7	3,55	11	5,58
		ProQuest	4	2,03		
	2016	YÖK Thesis	9	4,57	17	8,63
		ProQuest	8	4,06		
	2017	YÖK Thesis	9	4,57	14	7,11
		ProQuest	5	2,54		
	2018	YÖK Thesis	12	6,09	17	8,63
		ProQuest	5	2,54		
	2019	YÖK Thesis	25	12,69	32	16,24
		ProQuest	7	3,55		
	2020	YÖK Thesis	7	3,55	13	6,60
		ProQuest	6	3,05		
	2021	YÖK Thesis	13	6,60	14	7,11
		ProQuest	1	0,51		
	2022	YÖK Thesis	28	14,21	32	16,24
		ProQuest	4	2,03		
	2023	YÖK Thesis	21	10,66	22	11,17
		ProQuest	1	0,51		
Sum			**197**	**100**	**197**	**100**

As can be seen in Table 1, there are a total of 197 theses in the YÖK Thesis and ProQuest databases in the period between 2013-2023. While there were 10 theses (5.08%) in 2013, the number of theses increased in 2014 and 2016, with 15 theses (7.61%) and 17 theses (8.63%) registered, respectively. In 2019 and 2022, the highest number of theses was reached, and 32 theses (16.24%) were prepared in both years. In 2023, this number is 22 (11.17%). This distribution shows that there was a significant increase in theses related to mathematical modeling, especially in 2019, while the number of theses decreased in 2020 and 2021, and there was a significant increase again in 2022.

The distribution of theses by year on the basis of the database is presented in Figure 2 and

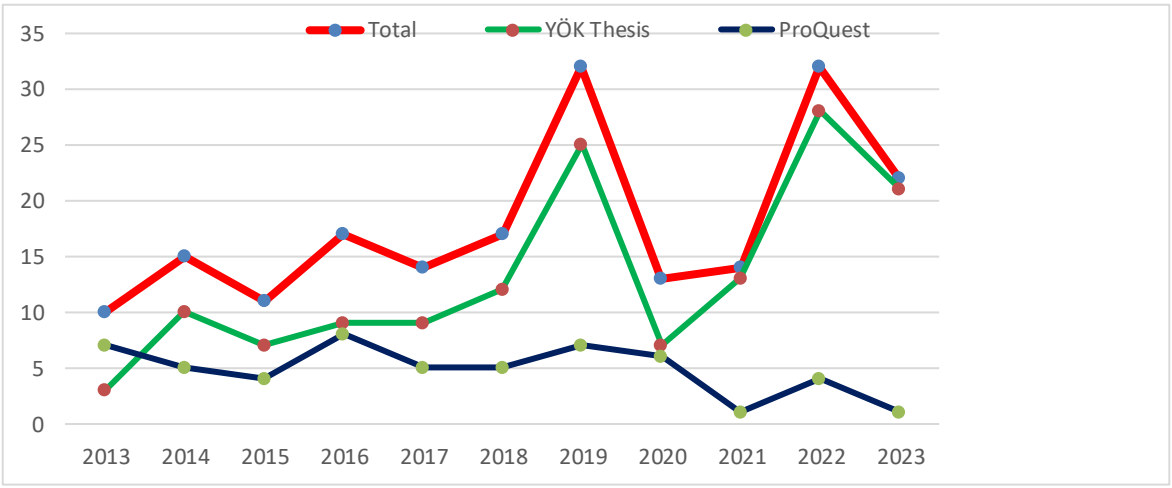


Figure 3.

Figure 2. Distribution of theses related to mathematical modeling in YÖK Thesis and ProQuest databases by years

As can be seen in Figure 2, while the distribution of YÖK Thesis database, which includes domestic theses, is more fragile by year, the number of theses in the ProQuest database, which includes international publications, provides a more stable graph. In terms of the total number of theses, it is seen in Figure 4.2 that there has been an increase in the rate of theses in the domestic YÖK Thesis database in recent years.

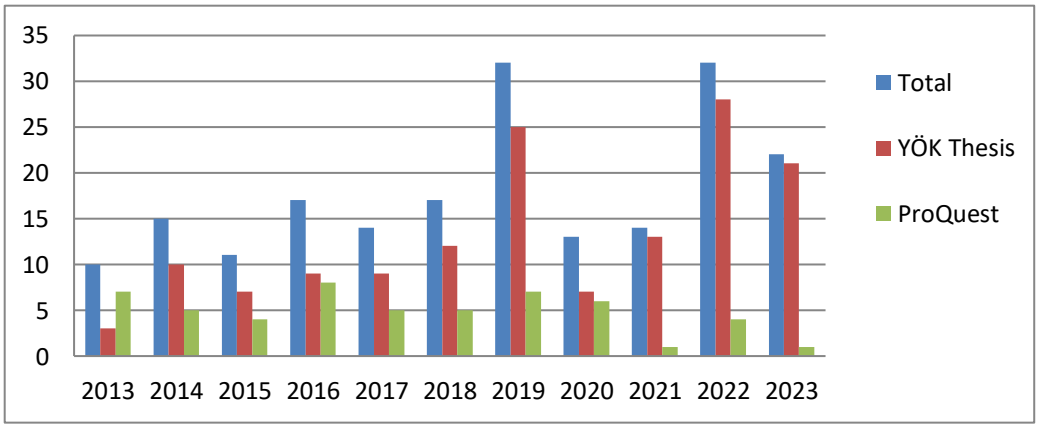


Figure 3. Distribution of theses related to mathematical modeling in YÖK Thesis and ProQuest databases by years

Considering the distribution of master's and doctoral theses in the field of mathematical modeling over the years and the differences on the basis of countries; In 2019 and 2022, there was a significant increase in the number of theses. This finding is in line with the research

results of Eryiğit (2022) and Koç (2020) that their mathematical modeling theses reached their peak in 2019. It can be thought that innovative approaches in the field of mathematics education at the global level may have gained momentum during these periods. Mathematical modeling has been seen as an effective tool in producing solutions to educational problems in recent years, and the increase in this interest is reflected in thesis studies. It can be said that developments in digital transformation and distance education are especially effective in this increase.

The reorganization of the Mathematics Course Curriculum in 2013 is also an important factor in the increase in theses. When we look at the Mathematics Applications Course Curriculum (2018), it *is stated that "modeling is included*". In this context, it can be said that the program can also guide the research. The decrease in the number of theses in 2020 and 2021 can be explained by the disruptions in academic processes due to the COVID-19 pandemic. While the pandemic has created a great transformation in education, it has also created serious difficulties in conducting research. Obstacles in the adaptation to distance education processes and data collection may have caused thesis studies to be postponed or restricted. However, the fact that there is a general upward trend in the number of theses in the YÖK Thesis database even in this period shows that researchers continue their work despite these difficulties and that the interest in mathematical modeling continues.

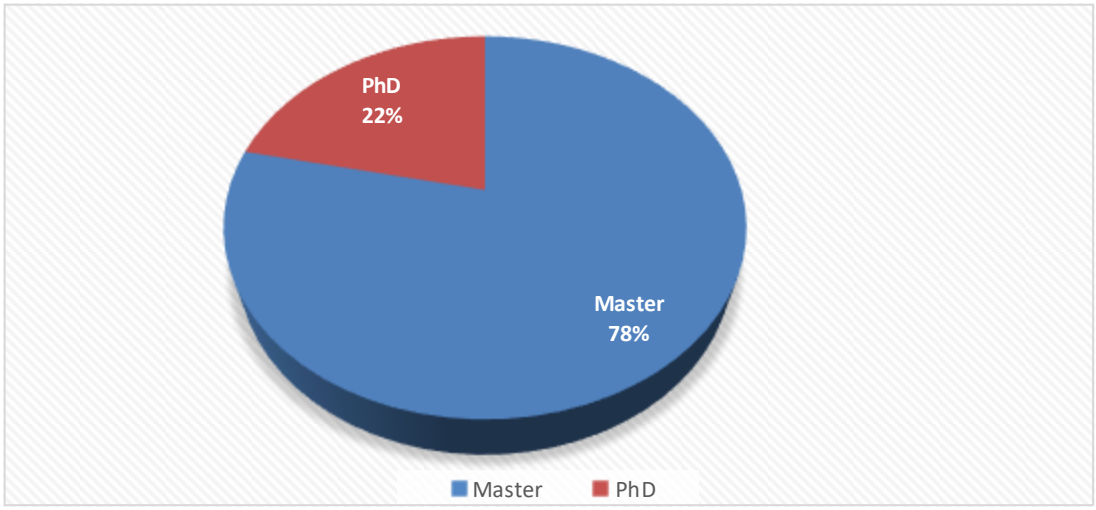
The distribution of master's and doctoral theses related to mathematical modeling prepared in the field of mathematics education according to the countries where they were made in terms of thesis type is presented in Table 2.

Table 2. Distribution of theses related to mathematical modeling included in the research according to the countries where they were made in terms of thesis type

Country	**Thesis Type**	***f***	**% (Country)**
Turkey	Master	113	78,47
	Doctorate	31	21,53
	Total	144	100
USA	Master	6	11,54
	Doctorate	46	88,46
	Total	52	100
Canada	Master	0	0,00
	Doctorate	1	100,00
	Total	1	100
Sum		**197**	**100**

Table 3 shows the distribution of master's and doctoral theses on mathematical modeling in the field of mathematics education by country. A total of 197 theses from Turkey, USA and Canada are included in the research.

The majority of theses in Turkey are master's theses; He has 113 master's theses (78.47%) and 31 doctoral theses (21.53%). In total, 144 theses from Turkey were recorded. In the USA, on the other hand, doctoral dissertations are predominant. There are 6 master's theses (11.54%) and 46 doctoral theses (88.46%) in the USA, with a total of 52 theses. Only 1 doctoral thesis (100.00%) from Canada was included in the research. The findings regarding the distribution of master's and doctoral theses in Turkey and the USA are presented in Figure 4.3 and Figure 4.4.



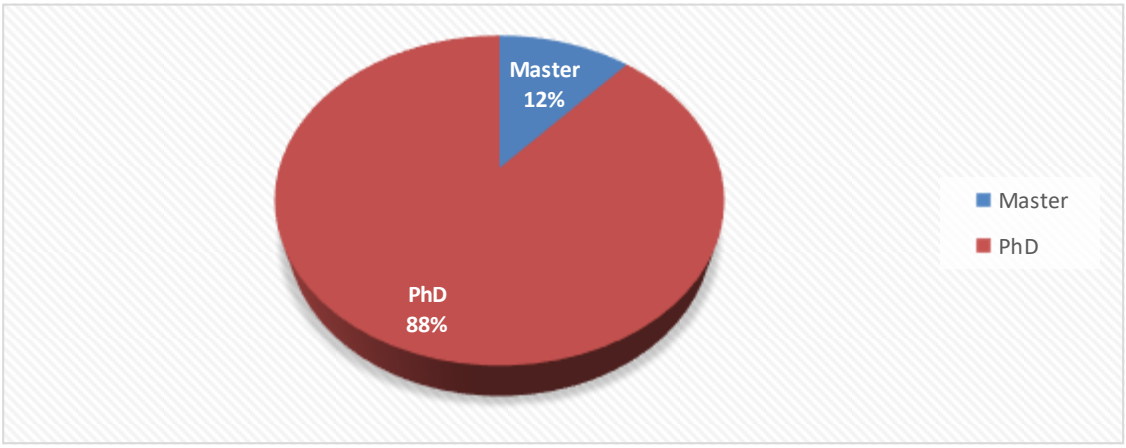
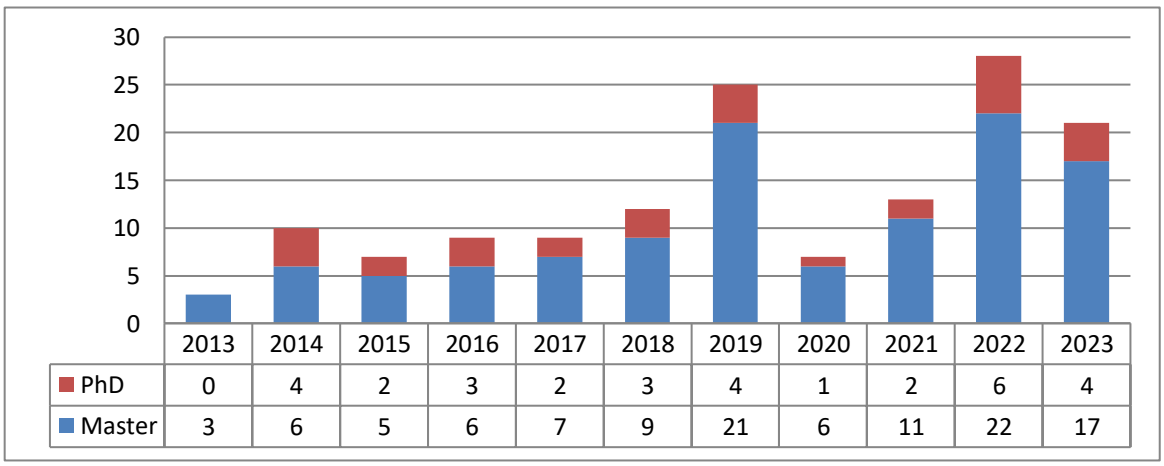


Figure 4. Distribution of theses on mathematical modeling in Turkey by genre

Figure 5. Distribution of theses on mathematical modeling in the USA and Canada by type

This distribution shows that the vast majority of studies on mathematical modeling in Turkey are at the master's level, while doctoral studies are more common in the USA and Canada.

The distribution and rates of the relevant domestic theses by year in terms of their types are presented in Figure 6 and Figure 7.

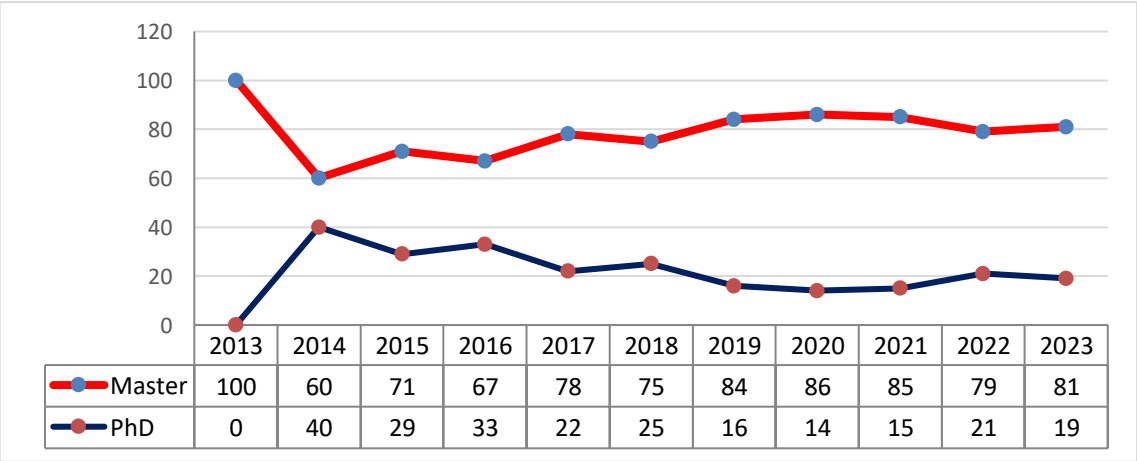


	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
PhD	0	4	2	3	2	3	4	1	2	6	4
Master	3	6	5	6	7	9	21	6	11	22	17

Figure 6. Distribution of theses on domestic mathematical modeling by years on the basis of their types

When the distribution of master's and doctoral theses on mathematical modeling in Turkey by year is examined on the basis of types, a significant upward trend is observed in master's theses. While there were only 3 master's theses in 2013, this number has increased every year. In particular, master's theses, which reached 21 in 2019, reached the highest level by increasing to 22 in 2022. However, there was a certain decrease in 2020 with 6 theses. In 2023, the number of master's theses was recorded as 17.

In terms of doctoral theses, it is seen that there were no doctoral theses in 2013. While 4 doctoral theses were written in 2014, 2 doctoral theses were written in 2015, 3 in 2016 and 2 again in 2017. In 2018 and 2019, more attention was paid with 3 and 4 doctoral theses, respectively. While 1 doctoral thesis was written in 2020, 2 doctoral theses were submitted in 2021, 6 in 2022 and 4 in 2023.

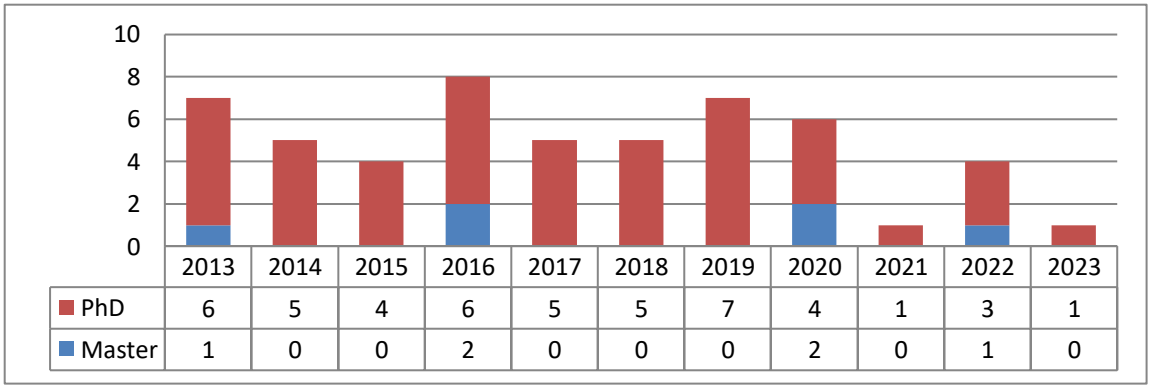


	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Master	100	60	71	67	78	75	84	86	85	79	81
PhD	0	40	29	33	22	25	16	14	15	21	19

Figure 7. Proportion of theses on domestic mathematical modeling by years on the basis of their types

When the ratios of master's and doctoral theses on mathematical modeling in Turkey are examined by year, master's theses generally have a high rate, while doctoral theses take place at a lower rate. In 2013, the rate of master's theses was 100%, while the rate of doctoral theses was recorded as 0%. In 2014, master's theses increased by 60% and doctoral theses increased by 40%. In 2015, the master's thesis rate was 71% and the doctoral thesis rate was 29%. In the following years, the master's thesis rate generally varied between 60% and 100%, while the doctoral thesis rate fluctuated between 0% and 40%. Especially in 2016, the master's thesis rate was recorded as 67% and the doctoral rate as 33%. In 2019, the master's thesis rate decreased to 84% and the doctoral rate to 16%. In 2020, the master's rate was 86% and the doctorate rate was 14%, while in 2021, these rates were 85% and 15%, respectively. In 2022, the master's thesis rate increased to 79% and the doctoral thesis rate increased to 21%. As of 2023, the master's rate was recorded as 81% and the doctorate rate was 19%.

The distribution and rates of the relevant overseas theses by year in terms of their types are presented in Figure 8 and Figure 9.

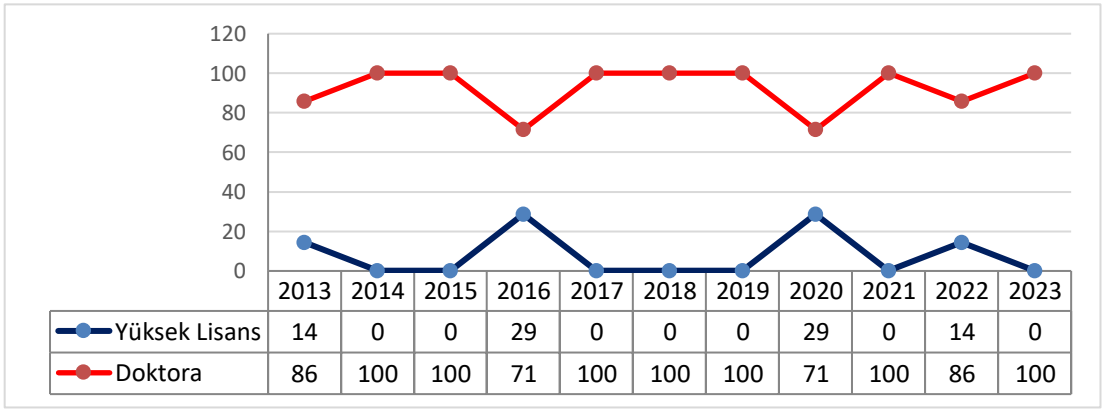


	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
PhD	6	5	4	6	5	5	7	4	1	3	1
Master	1	0	0	2	0	0	0	2	0	1	0

Figure 8. Distribution of theses related to mathematical modeling abroad by years on the basis of their types

When the distribution of theses related to mathematical modeling abroad is examined by years on the basis of their types, significant fluctuations are observed in master's and doctoral theses. While there was 1 master's and 6 doctoral theses in 2013, there were no master's theses in 2014 and 2015, and doctoral theses were recorded as 5 and 4, respectively. In 2016, the number of master's theses increased to 2 and the number of doctoral theses became 6.

While there were no master's theses in 2017 and 2018, 5 doctoral theses were written in both years. In 2019, the number of doctoral theses increased to 7, and again no master's thesis was registered. In 2020, there were 2 master's and 4 doctoral theses, while only 1 doctoral thesis was written in 2021. In 2022, 1 master's and 3 doctoral theses were recorded, while in 2023 there is only 1 doctoral thesis. In this context, it can be said that the number of master's theses is low, while the number of doctoral theses increases from time to time.



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Yüksek Lisans	14	0	0	29	0	0	0	29	0	14	0
Doktora	86	100	100	71	100	100	100	71	100	86	100

Figure 9. The ratio of theses on mathematical modeling ProQuest by years on the basis of their types

When the rates of theses related to mathematical modeling abroad are examined by years on the basis of their types, the rate of master's theses was recorded as 14% and the rate of doctoral theses as 86% in 2013. In 2016, the rate of master's theses increased to 29%, while the rate of doctoral theses was determined as 71%.As of 2017, master's theses have not been completely registered; The rate of doctoral theses was observed to be 100% every year. In 2020, the master's rate increased again to 29%, and the doctoral rate was determined as 71%. In 2021, no master's thesis was written, and the rate of doctoral thesis was again 100%. In 2022, the master's thesis rate was recorded as 14% and the doctoral thesis rate was 86%, while in 2023, only doctoral thesis was included and this rate was 100%.

When the types of theses by country are examined, it is seen that master's theses are dominant in Turkey. This finding is in line with the research results of Albayrak (2017), Koç (2020) and Eryiğit (2022). This situation shows that mathematics education programs in Turkey are

structurally concentrated at the master's level and doctoral studies remain relatively limited. This trend in Turkey can be explained by the fact that master's degree is seen as the first step for students aiming for an academic career and doctoral programs are more selective and challenging (Çarıkcı and Uluğ, 2024). Nevertheless, the increase in doctoral theses in 2022 may indicate that doctoral studies are increasingly preferred. The predominance of doctoral theses in the USA shows that the academic system in the USA has a doctorate-oriented structure. In the U.S., doctoral programs are often run with more resources and support, which increases the quality and number of research. In addition, the increase observed in doctoral dissertations shows that the subject of mathematical modeling is more accepted in academic circles in the United States and studies in this field are becoming widespread. The low number of master's theses indicates a trend in the U.S. where graduate studies are directed towards the doctoral level (Barnett, Harris, & Mulvany, 2017). The fact that there is only one doctoral dissertation in Canada shows that the work done on mathematical modeling in this country is limited. The reasons for this may include Canada's education policies, support for academic research, and relatively low interest in mathematics education. However, the fact that Canada is represented by a single thesis in this field may be due to the fact that the studies are included in different databases.

These differences between countries in terms of thesis types are due to the structural features of their education systems. Since countries such as Turkey and the USA have different academic cultures, trends regarding the types and numbers of theses also differ. While master's programs are more common in Turkey, doctoral programs in the USA stand out as a central element of an academic career. These differences show how educational policies and academic priorities are shaped in different countries. The increase in the number of theses in general since 2013 shows that new research topics in the field of mathematical modeling have become popular, especially in these periods (Aztekin and Şener, 2015). During these years, the increasing interest in STEM (Science, Technology, Engineering and Mathematics) fields around the world has also encouraged studies on mathematical modeling. In particular, the development of educational technologies and the fact that modeling tools have become more accessible may have led researchers to write theses in this field.

Another data analyzed within the scope of the first research question of the research is the distribution of theses on mathematical modeling according to universities. The findings regarding the distribution of theses made in Turkey according to universities and the information of advisors at the university are presented in Table 3 and Table 4.

Table 3. Distribution of theses on mathematical modeling by universities in Turkey

University	Frequency	Percentage (%)
Ataturk University	14	9,72
Erzincan Binali Yildirim University	10	6,94
Gazi University	8	5,56
METU	8	5,56
Anadolu University	7	4,86
Hacettepe University	7	4,86
Marmara University	6	4,17
Adiyaman University	5	3,47
Balıkesir University	5	3,47
Çukurova University	5	3,47
Eskisehir Osmangazi University	5	3,47
Dicle University	4	2,78
Firat University	4	2,78
Akdeniz University	3	2,08
Kocaeli University	3	2,08
Mersin University	3	2,08
Necmettin Erbakan University	3	2,08
Ondokuz Mayıs University	3	2,08
Van Centennial University	3	2,08
Zonguldak Bulent Ecevit University	3	2,08
Bolu Abant İzzet Baysal University	2	1,39
Dokuz Eylul University	2	1,39
Erciyes University	2	1,39
Karadeniz Technical University	2	1,39
Kastamonu University	2	1,39
Nigde Omer Halis Demir University	2	1,39
Tokat Gaziosmanpasa University	2	1,39
Yildiz Technical University	2	1,39
Çukurova University	1	0,69
Abant izzet baysal University	1	0,69
Bartin University	1	0,69
Başkent University	1	0,69
Bursa Uludag University	1	0,69
Ege University	1	0,69
Gaziantep University	1	0,69
Gaziosmanpasa University	1	0,69
Gediz University	1	0,69
Giresun University	1	0,69
Istanbul University -Cerrahpasa	1	0,69
Kirsehir ahi Evran University	1	0,69
Karamanoglu Mehmet Bey University	1	0,69
Kutahya Dumlupinar University	1	0,69
Manisa Celal Bayar University	1	0,69
Pamukkale University	1	0,69
Recep Tayyip Erdogan University	1	0,69
Sivas Cumhuriyet University	1	0,69
Trabzon University	1	0,69
Sum	**144**	**100,00**

Looking at Table 3; Among a total of 144 theses, Atatürk University has the highest frequency and produced 14 theses with a rate of 9.72%. This is followed by Erzincan Binali Yıldırım University with 10 theses (6.94%), Gazi University and METU with 8 theses (5.56%) each. Among the other prominent universities, Anadolu University and Hacettepe University are at the forefront with 7 theses (4.86%) each, while Marmara University is at the forefront with 6 theses (4.17%). Dicle University and Fırat University are among the productive universities in mathematical modeling studies with 4 theses (2.78%).

The distribution of theses on mathematical modeling according to universities and academics shows that academic knowledge in this field is concentrated around certain institutions and individuals. The fact that Atatürk University ranks first among universities in Turkey with a rate of 9.72% indicates that this university has become an important academic center in the field of mathematical modeling. Relevant researches also indicate that Atatürk University is the university that produces the highest thesis in this field (Albayrak, 2017; Aries, 2020; Celebrity, 2020; Eryiğit, 2022). The fact that other universities such as Erzincan Binali Yıldırım University, Gazi University and METU have also produced remarkable studies in this field shows that the regional distribution in Turkey has begun to spread to a wide base. This distribution reveals that academic studies in the field of mathematical modeling are not limited to certain large cities, but also develop in universities in other provinces.

Table 4. Distribution of theses on mathematical modeling in Turkey by their clients

Name*	**Number of Theses**	**University**
Prof. Alper ÇİLTAŞ	7	Ataturk University
Prof. Mehmet BEKDEMİR	4	Erzincan Binali Yildirim University
Prof. Ramazan GÜRBUZ	4	Adiyaman University
Assoc. Prof. Dr. Zeynep ÇAKMAK GÜREL	3	Erzincan Binali Yildirim University
Prof. Ahmet Şükrü ÖZDEMİR	3	Marmara University
Prof. Ayten Pınar BAL	3	Çukurova University
Assoc. Prof. Dr. Şerife SEVİNÇ	3	METU
Prof. Esra BUKOVA GÜZEL	3	Dokuz Eylul University
Prof. Adnan BAKİ	3	Karadeniz Technical University
Prof. Yüksel DEDE	2	Gazi University
Assoc. Prof. Dr. Makbule Gözde DİDİDİŞ KABAR	2	Tokat Gaziosmanpasa University
Prof. Ali ERASLAN	2	Ondokuz Mayıs University
Prof. Hüseyin Bahadır YANIK	2	Anadolu University
Prof. İlhan KARATAŞ	2	Zonguldak Bulent Ecevit University
Assoc. Prof. Dr. Meryem ÖZTURAN SAĞIRLI	2	Erzincan Binali Yildirim University
Prof. Soner DURMUS	2	Abant izzet baysal University
Prof. Kemal ÖZGEN	2	Dicle University
Prof. Aytaç KURTULUŞ	2	Eskisehir Osmangazi University
Dr. Emine Aysın ŞENEL	2	Anadolu University
Prof. Dr. Pınar ANAPA SABAN	2	Eskisehir Osmangazi University

*Not all advisors are included in the ranking, but scientists who supervise more than one thesis are included.

When we look at the scientists who supervised the theses; Prof. Dr. Alper Çiltaş stands out in the field of mathematical modeling with 7 theses he has carried out at Atatürk University. Prof. Dr. Mehmet Bekdemir from Erzincan Binali Yıldırım University and Prof. Dr. Ramazan Gürbüz from Adıyaman University are thesis advisor academicians who have a say in the field with 4 theses. Assoc. Prof. Dr. Zeynep Çakmak Gürel (Erzincan Binali Yıldırım University), Prof. Dr. Ahmet Şükrü Özdemir (Marmara University), Prof. Dr. Ayten Pınar Bal (Çukurova University), Assoc. Prof. Dr. Şerife Sevinç (METU), Prof. Dr. Esra Bukova Güzel (Dokuz Eylül University) and Prof. Dr.

Adnan Baki (Karadeniz Technical University) are the scientists who contributed to the field with 3 theses.

The fact that Atatürk University in Turkey is a leader in the production of high theses on mathematical modeling shows that this university has a well-established strategic academic vision in this field and offers an attractive academic environment for researchers. Prof. Dr. Alper Çiltaş's prominence as the advisor who directed 7 theses also reflects his expertise in this field and the academic background at the university. Considering that a large part of the researcher's work has been in this field since 2019 (ATAUNI, 2024), and considering that the success of a university is directly related to the competence of individual academics in their field, Prof. Dr. Çiltaş's contribution can be considered as an important factor in explaining Atatürk University's leadership position in this field. When we look at other universities in Turkey, the fact that Erzincan Binali Yıldırım University ranks second and Prof. Dr. Mehmet Bekdemir's contributions in the consultancy process show that this university is also actively involved in the development process in the field of mathematical modeling. Considering that the researcher also did his doctoral work at Atatürk University, it can be said that the academic culture has moved to this university (EBYU, 2024). The fact that universities in smaller cities such as Erzincan have an important position in this field plays an important role in ensuring regional diversity. This may also be a reflection of the support provided to universities by regional development policies in Turkey's academic system. The fact that Gazi University and METU each produced 8 theses shows that these two universities have traditionally had a strong research history in the field of mathematics education and modeling. The well-established academic structures of both universities and the importance they attach to scientific research increase the continuity and quality of master's and doctoral theses in this field. Anadolu University and Hacettepe University have also played important roles in this process. In particular, Anadolu University's resources in the field of distance education and how this university contributes to the field of research can be examined in future research. The distribution of theses made in the USA and Canada by universities is presented in Table 5.

Table 5. Distribution of theses on mathematical modeling in the USA and Canada by universities

University	Frequency	Percentage (%)
Columbia University	8	15,09
The Ohio State University	5	9,43
North Carolina State University	2	3,77
Purdue University	2	3,77
Ohio University	2	3,77
University of Missouri	2	3,77
American College of Education	1	1,89
Boston College	1	1,89
City University of New York	1	1,89
Claremont Graduate University	1	1,89
Florida Institute of Technology	1	1,89
George Mason University	1	1,89
Harvard University	1	1,89
Kansas State University	1	1,89
Kent State University	1	1,89
Montana State University	1	1,89
Montclair State University	1	1,89
Piedmont Colage	1	1,89
San Diego State University	1	1,89
San José State University	1	1,89
Stanford University	1	1,89
The City University of New York	1	1,89
The State University of New Jersey	1	1,89
The University of Arizona	1	1,89
The University of Minnesota	1	1,89
The University of Georgia	1	1,89
The University of Iowa	1	1,89
The University of the Arts	1	1,89
The University of Utah	1	1,89
The University of Western Ontario	1	1,89
Universsıt´E de Montr´Eal	1	1,89
University of California	1	1,89
University of Florida	1	1,89
University of Massachusetts Lowell	1	1,89
University of Delaware	1	1,89
Utah State University	1	1,89
University of Nebraska	1	1,89
University of Colorado	1	1,89
Sum	**53**	**100,00**

When we look at the distribution of theses on mathematical modeling in the USA and Canada by universities, the university with the highest number is Columbia University with 8 theses and 15.09% of the theses. The Ohio State University, on the other hand, is a university that stands out with its theses on mathematical modeling with 5 theses. North Carolina State University, Purdue University, Ohio University, and the University of Missouri are on the list with 2 theses (3.77%) each. When the distribution in the USA and Canada is examined, it is noteworthy that Columbia University has the highest thesis production frequency. Columbia University's leadership in this field can be attributed to the breadth of research opportunities at prestigious

universities in the United States. Research-intensive universities, such as Columbia University, contribute to the advancement of academic studies in this field by offering ample resources to doctoral students.

Table 6. Advisor information for theses on mathematical modeling in the USA and Canada

Name	Number of Theses	University
Dr. Bruce Vogeli	5	Columbia University
Dr. Azita Manouchehri	4	The Ohio State University
Dr. Gregory Dean Foley	2	Ohio University
Dr. Lillie Richardson Albert	2	Boston College
Dr. Karen Allen Keene	2	North Carolina State University

When we look at the advisor information of the theses made in the USA and Canada; With 5 theses, Dr. Bruce Vogeli from Columbia University is in first place. She is followed by Dr. Azita Manouchehri from The Ohio State University with 4 theses. Other advisors include Dr. Gregory Dean Foley of Ohio University, Dr. Lillie Richardson Albert of Boston College, and Dr. Karen Allen Keene of North Carolina State University, each with 2 theses.

Dr. Bruce Vogeli's advisory role in this field and the abundance of citations he has received is another factor that strengthens Columbia University's position as a leader in the field of mathematical modeling. It is seen that The Ohio State University has made an important contribution in this field with 5 theses. The Ohio State University's strong academic infrastructure and studies in this field allow the university to make a name for itself in the international arena. Dr. Azita Manouchehri's prominence as the advisor who guided the 4 theses reflects the academic know-how of this university in the field of mathematical modeling. The academic experience of the advisors directly affects the quality of the theses and their impact in the field. This situation has been observed in a similar way in Turkey, and the contributions of consultants to the field appear as a determining factor for the success of the university in international platforms (Balcı, 2013).

The results of the density analysis of citations, which is another technique in revealing the relevant scientists in the theses on mathematical modeling, are presented in Figure 10.

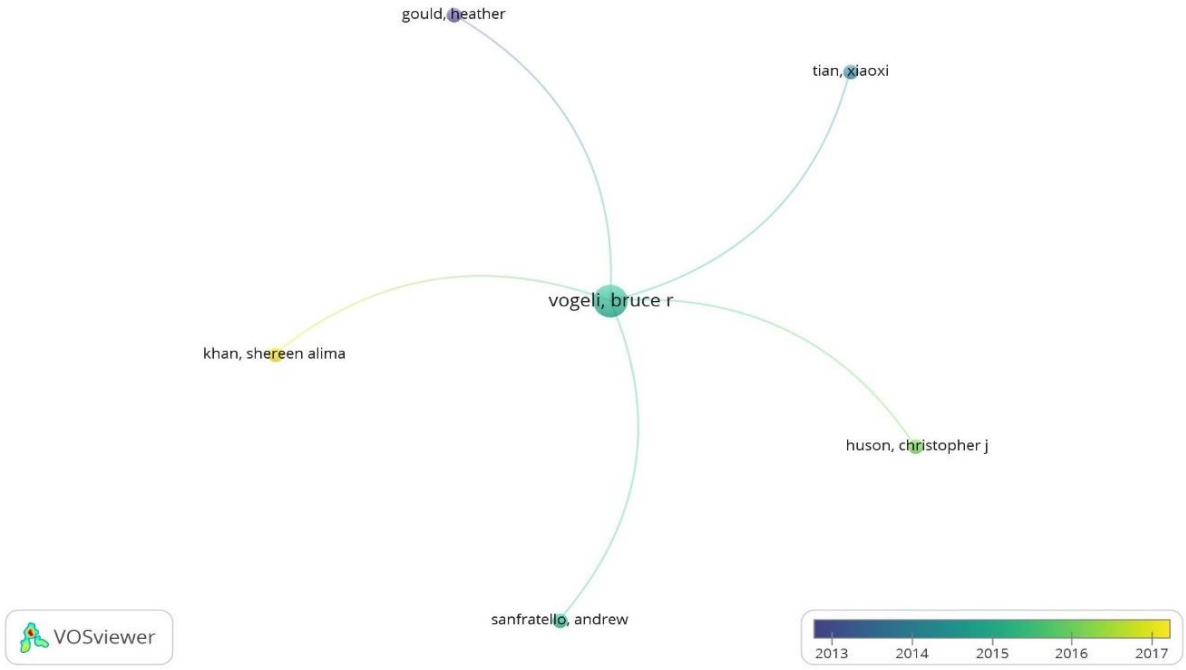


Figure 10. Density analysis results of thesis citations

As can be seen in Figure 10, when the results of the density analysis of thesis citations are examined, it is seen that the most cited researcher in this field is Dr. Bruce Vogeli.

The distribution of national and international master's and doctoral thesis topics related to mathematical modeling in the field of mathematics education and their changes by years are presented in Figure 11, Figure 12 and Table 7.

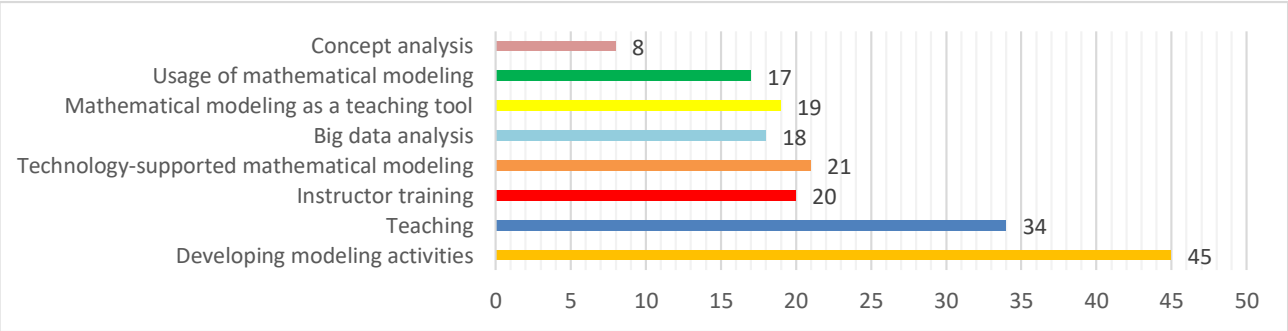


Figure 11. General distribution of thesis topics related to mathematical modeling

When we look at the distribution of mathematical modeling subjects; The most common topic was developing modeling activities, with 45 studies. This is followed by teaching with 34 studies and mathematical modeling with 27 studies. Other prominent topics include technology-assisted mathematical modeling (21 studies), tutorial training (20 studies), the use of mathematical modeling as a mathematics teaching tool (19 studies), and big data analysis (18 studies). Concept analysis, on the other hand, has been less studied and has been discussed in 8 studies.

Table 7. Changes in thesis topics related to mathematical modeling over the years

Topic	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Sum**
Developing modeling activities	3	2	2	3	3	6	5	6	5	5	5	45
Teaching	1	2	1	3	4	4	5	1	2	5	6	34
Tutorial training	1	2	1	1	2	2	4	0	0	4	3	20
Technology-enabled mathematical modeling	0	1	2	2	2	3	2	1	2	3	3	21
Big data analytics	0	1	1	1	1	2	2	1	3	3	3	18
Mathematical modeling as a mathematics teaching tool	1	1	1	2	2	2	1	1	2	3	3	19
How to use mathematical modeling	1	2	2	1	1	1	3	4	4	5	3	27
Concept Analysis	0	0	1	0	1	2	0	0	0	2	2	8
Sum												192

Between 2013 and 2023, when we look at the distribution of thesis topics by years; The topic of developing modelling activities has been studied regularly throughout all years and has been addressed in high numbers, especially in 2018 and beyond. This topic varied between 2 and 6 theses each year and was the most studied area with a total of 45 theses. The topic of teaching has received increasing attention since 2017 and reached the highest number (6 theses) in 2023. With 34 theses, this field ranks second. Tutorial training, on the other hand, exhibited a more irregular distribution, especially in 2019, while no theses were made, it remained between 2-4 theses on average in other years. This field occupies an important place with a total of 20 theses. The annual number of theses on technology-supported mathematical modeling remained constant, with the highest publication in 2018, 2022 and 2023 with 3 theses. This topic stands out with 21 theses.

The subject of big data analysis has increased since 2017, especially in recent years (2021-2023) and contributed with 3 theses every year. A total of 18 theses have been written in this field.

Mathematical modeling as a means of teaching mathematics has increased since 2017 and has been the subject of steady interest for the last three years, with 3 theses each year. A total of 19 theses have been produced in this field. The use of mathematical modeling has also attracted high attention, especially between 2019 and 2022, with a number of studies ranging from 3 to 5 theses each year, reaching a total of 27 theses.

Concept analysis, on the other hand, has been less studied compared to other topics, it has only been addressed with a few studies in 2015, 2017, 2018, 2022 and 2023, and a total of 8 theses have been produced.

The annual distribution of theses on mathematical modeling by topic and learning areas shows that academic trends and developments in this field should be carefully examined. According to the findings, the topic of developing modeling activities was the most widely studied area with 45 theses. This situation reveals the breadth and importance of the application area of mathematical modeling activities in education (Albayrak, 2017; Aries, 2020; Celebrity, 2020). Modeling activities have pedagogical value for both teachers and students, as they help teach mathematical concepts in a more concrete and understandable way (Eryiğit, 2022).

The fact that the subject of teaching ranks second with 34 studies shows that the subject of mathematical modeling has become an important focus of interest on its practical applications in education. The increasing number of theses in this field since 2017 reveals that the use of modeling in mathematics teaching is gaining more and more importance. The fact that this trend peaked in 2023 indicates that modeling in education is being adopted as a more common teaching strategy. In addition, 20 theses on teacher education support the efforts of mathematics teachers to improve their knowledge and skills in this field.

The use of mathematical modeling is another prominent topic with 27 theses. The fact that interest in this field has increased between 2019 and 2022 shows that studies questioning and investigating the effectiveness of the use of mathematical modeling in education have intensified during this period. This increase may be a result of a better understanding of the pedagogical value of modeling in teaching methods and its integration into educational processes (Sönmez, 2016). It can be said that studies on the effect of modeling methods on improving students' problem-solving skills have a share in this increase in interest. Technology-supported mathematical modeling stands out as an important research area with a total of 21 theses. The digital transformation brought about by the 21st century has led to the need to support mathematics education with digital tools and technologies (Gopal, 2020). In this context, it is seen that students who do mathematical modeling using technology better understand and apply abstract mathematical concepts (Albayrak, 2017).

The relationship between big data analysis and mathematical modeling may also have contributed to increased research in this area. The increase in the subject of big data analysis since 2017 and the continuous contribution to the field between 2021-2023 show that secondary data research such as systematic scanning, meta-analysis, meta-thematic analysis and bibliometric analysis is increasingly used. This trend can be explained by the ease of access to data brought by the digital age. Big data analysis has enriched the modeling process by providing a broader perspective in students' and teachers' understanding of mathematical processes (Donthu et al. 2021). The popularity of this field in recent years shows that data-driven research and education models will become widespread in the future.

The fact that the use of mathematical modeling has received a steady interest as a mathematics teaching tool since 2017 reveals that this method has become a permanent strategy in teaching. The fact that 19 theses have focused on this area shows that modeling is an effective method for explaining mathematical concepts. This result similarly coincides with the work of Aztekin and Şener (2015) and Albayrak and Çiltaş (2017) Modeling can be considered as a sustainable tool in mathematics teaching, as it offers students the opportunity to solve real-life problems and make sense of abstract concepts (Sönmez and Şahin, 2016; Alkan and Aydin, 2019). Less interesting topics, such as concept analysis, have been limited to only 8 theses. This shows that conceptual

analyses have not yet been fully explored in mathematical modeling or received sufficient attention in practice. New studies on concept analysis can strengthen the theoretical infrastructure of this field and add a new dimension to modeling processes.

Another method used to determine the topics and themes of the theses is the density analysis of keywords. The keyword analysis in this context is presented in Figure 12.

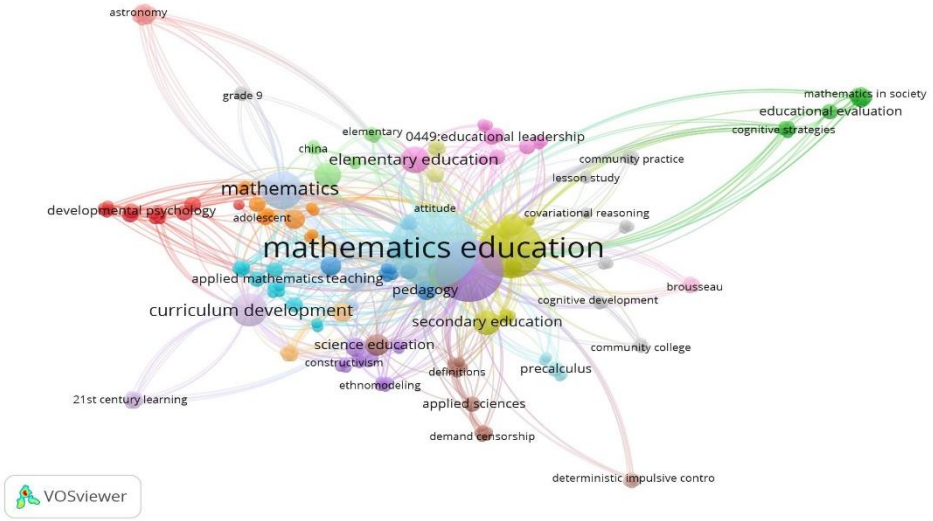


Figure 12. Density analysis of keywords in theses on mathematical modeling

Looking at Figure 12; The keywords in the theses are mathematics education, applied mathematics teaching, modeling, mathematics, curriculum development, secondary school education, cognitive strategies, mathematics in society, attitude. It is seen that he concentrates on words such as century skills and constructivism.

The total distribution of the learning areas of the theses and the changes according to the years are presented in Figure 13.

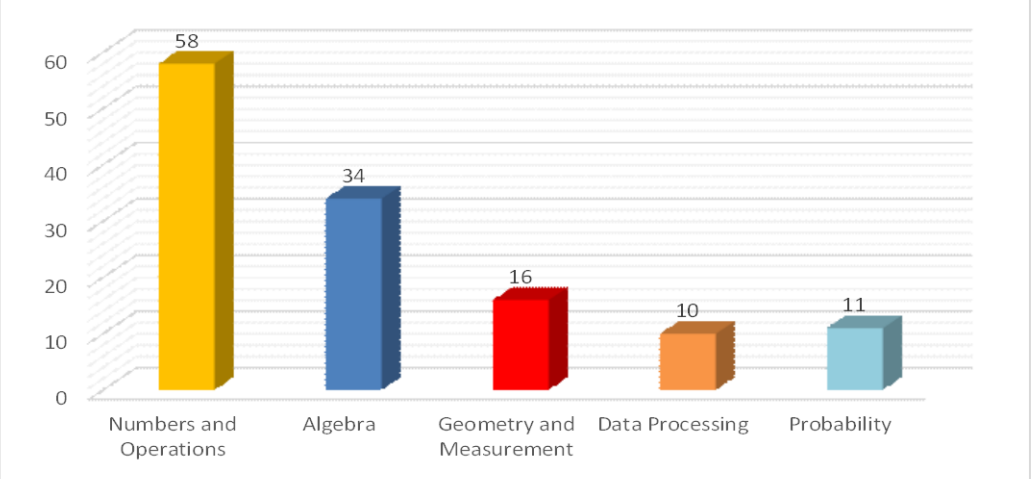


Figure 13. Distribution of learning areas of thesis topics related to mathematical modeling

Considering the distribution of learning areas; the most studied area is "Numbers and Operations" with 58 theses. This is followed by "Algebra" with 34 theses. Other areas are less studied and are represented by "Geometry and Surveying" with 16 theses, "Probability" with 11 theses and "Data Processing" with 10 theses. This distribution shows that numbers and operations are the most focused learning area.

Learning areas are divided into Numbers and Operations, Data Processing, Geometry and Measurement, Algebra and Probability in the Mathematics Curriculum (2018). The changes in the learning areas of the theses according to the total years are presented in Table 4.8.

Table 8. Changes in the learning areas of the theses over the years

Learning Area	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Sum
Numbers and Operations	1	4	3	5	4	5	9	4	5	7	11	58
Algebra	1	2	2	3	2	3	5	1	5	4	6	34
Geometry and Surveying	0	2	0	2	2	2	2	1	0	3	2	16
Data Processing	1	2	1	2	2	0	0	1	0	1	0	10
Probability	1	1	0	2	1	1	1	0	1	2	1	11

Between 2013 and 2023, the most studied area in the learning areas was *Numbers and Operations, which were studied regularly every year*, and took the highest place in total with 58 theses. In particular, in 2023, 11 theses were made in this field. Algebra ranked second with 34 theses and reached the high number of theses in 2019 and 2023. 16 theses were made in the field of Geometry and Surveying, and this subject was studied further, especially in 2014 and 2022. The field of Data Processing was examined less with a total of 10 theses, and there was a decrease in interest in 2018 and beyond. The field of probability was limited to a total of 11 theses and attracted more attention, especially in 2016 and 2022.

In the distribution made according to learning areas, the subject of "Numbers and Operations" was the most studied field with 58 theses. This shows that numbers and operations have a fundamental role in the mathematical modeling process. In particular, 11 theses produced in this field in 2023 show that the relationship between modeling activities and numerical operations is examined in more depth. Since numbers and operations are the basis of mathematical modeling, interest in this field is expected to increase." The subject of "Algebra" ranks second with 34 theses and reached a high number of theses in 2019 and 2023. Since algebraic concepts are structures that are frequently used in mathematical modeling, the intensification of studies in this field reveals the potential for modeling processes to be applied to more abstract mathematical concepts (Eryiğit, 2022).

16 theses have been produced in the field of "Geometry and Measurement", and further study of this field, especially in 2014 and 2022, shows that the relationship between geometry and modeling has been intensively examined in certain periods. Since geometry gives a visual and structural dimension to mathematical modeling, thesis studies in this field are of great importance. Teaching students about geometric concepts through modeling can be beneficial in terms of embodying abstract geometry concepts. The field of "Data Processing" stands out as a less studied subject with a total of 10 theses. The decrease in interest in this field, especially after 2018, may indicate that the place of data processing techniques in modeling processes is limited or does not attract as much attention as other fields. However, data-driven analysis and data processing techniques can be integrated with big data analysis, and it can be foreseen that this field may gain renewed attention in the future. The field of "probability" was also limited to 11 theses, and attracted more attention, especially in 2016. This finding is similar to the research results of Eryiğit (2022). Although probability and statistical modeling have an important role in mathematical modeling processes, the lack of interest in this field can be explained by the difficulty of probability theory in modeling processes or the fact that it is not used as widely as other fields.

Findings and Discussion on the Second Sub-Research Question

The analysis of the methodological features of the master's and doctoral theses related to mathematical modeling prepared in the field of mathematics education and the distribution and changes over time was carried out within the scope of the second research question.

In this context, the research method distributions of national and international master's and doctoral theses related to mathematical modeling prepared in the field of mathematics education are presented in Table 9 and Figure 14.

Table 9.Research method distributions of theses on mathematics education

Variable	Method	Number (n)	%
Research Methodology	Qualitative	121	61,42
	Hash	49	24,87
	Quantitative	27	13,71
Sum		**197**	**100,00**

Table 9 shows the distribution of research methods used in the theses. The most commonly used method was qualitative research with 61.42% and 121 theses used this method. The mixed method was applied in 49 theses with a rate of 24.87%, and quantitative research was applied in 27 theses with a rate of 13.71%.

The change in the research methods of master's and doctoral theses related to mathematical modeling prepared in the field of mathematics education by years is presented in Table 10 and Figure 14.

Table 10. Change in research methods of theses on mathematics education over the years

Research Methodology	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Sum**
Qualitative	7	8	7	11	7	9	19	8	7	21	17	121
Mixed	1	3	4	4	6	5	11	3	4	6	2	49
Quantitative	2	4	0	2	1	3	2	2	3	5	3	27

According to Table 10; The qualitative research method was used most frequently in 2019 with 19 theses, and especially increased with 21 theses in 2022. The years in which the qualitative research method was used the least were 2013 and 2015, and 7 theses were made with this method in these years. The mixed method reached the highest level with 11 theses in 2019 and was used at lower levels (3-4 theses) in the 2020-2021 period. Quantitative research, on the other hand, is the least preferred method, and it is noteworthy that 2015 was not done with any thesis. The years in which it was used the most were 2022 and 2023, and it was included in 5 and 3 theses in both years. In 2013 and 2019, this method was applied a limited number of times (2 theses).

It is seen that the qualitative research method is the most frequently used method in mathematical modeling theses. The distribution of research methods by years shows that qualitative research comes to the fore in theses. The predominant preference for qualitative research with a rate of 61.42% shows that researchers adopt an approach to obtain in-depth information and to understand the perspectives of individuals in more detail. While this contributes to the understanding and interpretation of complex processes in the field of education, the reason why it is less preferred than quantitative research is that such researches generally give general results and do not offer process-oriented analysis. In studies abroad, it is seen that the interest in qualitative methods has increased in recent years (Kelly and Lesh, 2000). Hart et al. (2009) examined the methods of studies carried out in the field of mathematics education between 1995 and 2005 and found that qualitative research methods were more widely used in this period. This finding is similar to the situation in Turkey (Göktaş et al., 2012; Albayrak, 2017; Eryiğit, 2022). Studies by Göktaş et al. (2012) also revealed that qualitative and mixed research methods are increasingly preferred, while quantitative methods have begun to lose their effectiveness. The fact that mixed methods are preferred at a rate of 24.87% shows that researchers prefer to perform more comprehensive analysis by combining the advantages of both methods. The frequent use of mixed methods, especially after 2019, as it allows both

qualitative and quantitative data to be analyzed together, reveals that this method has been preferred more recently. The fact that quantitative research is less preferred with a rate of 13.71% may be related to the fact that this method does not provide comprehensive enough information to explain abstract processes in education.

The details of the theses in terms of research models are presented in Table 11 and Figure 14.

Table 11. Distribution of research models of theses on mathematical modeling

Variable	Model	Number (n)	%
Research Model	Case Study	117	59,39
	Experimental Study	32	16,24
	Teaching Experiment	13	6,60
	Action Research	13	6,60
	Scan Model	11	5,58
	Meta-analysis	5	2,54
	Document Analysis	3	1,52
	Design-Based Model	3	1,52
Sum		**197**	**100,00**

Table 11 shows the distribution of research models used in the theses. The most common model was the case study with a rate of 59.39% and was used in 117 theses. While the experimental study ranked second with 16.24%, the teaching experiment and action research were used in 13 theses with a rate of 6.60%. Other models include the scanning model with 5.58%, the meta-analysis with 2.54%, and the document analysis and design-based model with 1.52%.

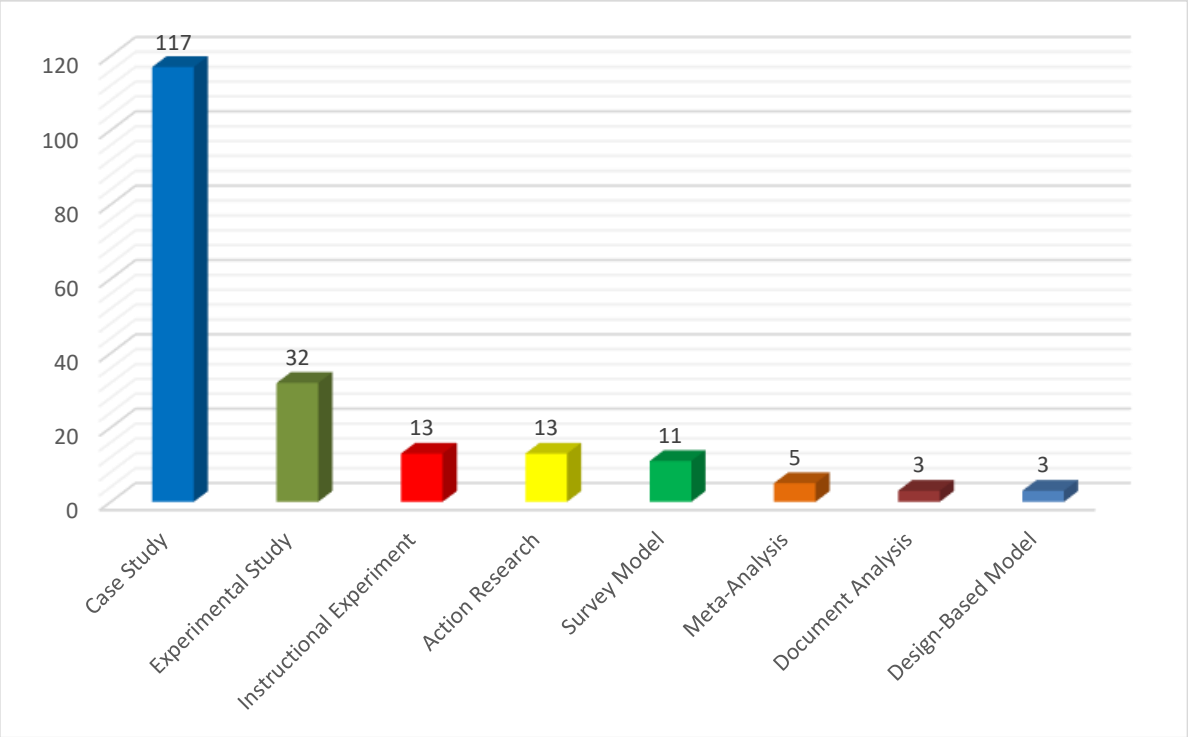


Figure 14. Distribution of theses on mathematical modeling according to research models

Details showing the change in theses in terms of research models over the years are presented in Table 12.

Table 12. Change of research models of theses on mathematical modeling by years

Research Model	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**Sum**
Case Study	8	7	8	10	7	7	20	8	5	21	16	117
Experimental Study	1	6	0	2	2	4	7	2	5	3	0	32
Teaching Experiment	0	0	2	1	1	2	2	1	2	2	0	13
Action Research	0	1	0	1	1	2	1	1	0	3	3	13
Scan Model	1	0	0	1	0	2	1	1	2	2	1	11
Meta-analysis	0	0	1	0	1	0	1	0	0	1	1	5
Document Analysis	0	1	0	0	2	0	0	0	0	0	0	3
Design-Based Model	0	0	0	2	0	0	0	0	0	0	1	3

Looking at Table 12, the change in the research models used in the theses between 2013-2023 by years; The case study is the most widely used model with a total of 117 theses, reaching the highest levels of use, notably in 2019 and 2022 with 20 and 21 theses, respectively. The experimental study was applied in 32 theses and was mostly preferred in 2014 and 2019. Other models, such as teaching experiment and action research, were included in 13 dissertations; Both models were mostly preferred in 2022 and 2023. The survey model has been used in 11 theses and has shown limited use over the years. Other models, such as meta-analysis, document analysis, and design-based model, have rarely been used.

Looking at the research models, the fact that the case study stands out as the most common model with a rate of 59.39% shows the importance of in-depth examination of specific events in studies in the field of education. This finding is similar to the research results of Aztekin and Şener (2015). The case study model allows researchers to gather more detailed information and interpret the results in a more holistic way by focusing on individual cases. It can be said that the frequent use of this model is due to the fact that it provides a significant advantage in terms of making complex educational processes more understandable. The fact that experimental studies are preferred by 16.24% indicates that some studies are generally carried out in line with the need to observe the effect of certain variables. However, this method may have been less preferred due to the difficulty of creating experimental conditions in educational settings. The use of teaching experiment and action research at a rate of 6.60% emphasizes the importance of including applications for practical education in research. Information about the sample types of theses related to mathematical modeling prepared in the field of mathematics education is presented in Table 13 and Figure 19.

Table 13. Distribution of theses on mathematical modeling according to sample types

Variable	**Sample**	**Number (n)**	**%**
Sample Type	Student	123	58,57
	Teacher Candidate	42	20,00
	Teacher	30	14,29
	Research	9	4,29
	MMA*	4	1,90
	Parent	2	0,95
Total*		**210****	**100,00**

* Mathematical Modeling Activities

**Since some studies work with more than one sample group, the total number is more than the number of studies.

According to Table 13, the most common sample type is students with 58.57% and they are at the center of research in 123 theses. This was followed by the sample of pre-service teachers with 20.00%, while teachers took part in 30 theses with a rate of 14.29%. Other sample types were used at lower rates, and the research sample was preferred by 4.29%, MMA by 1.90% and parent by 0.95%.

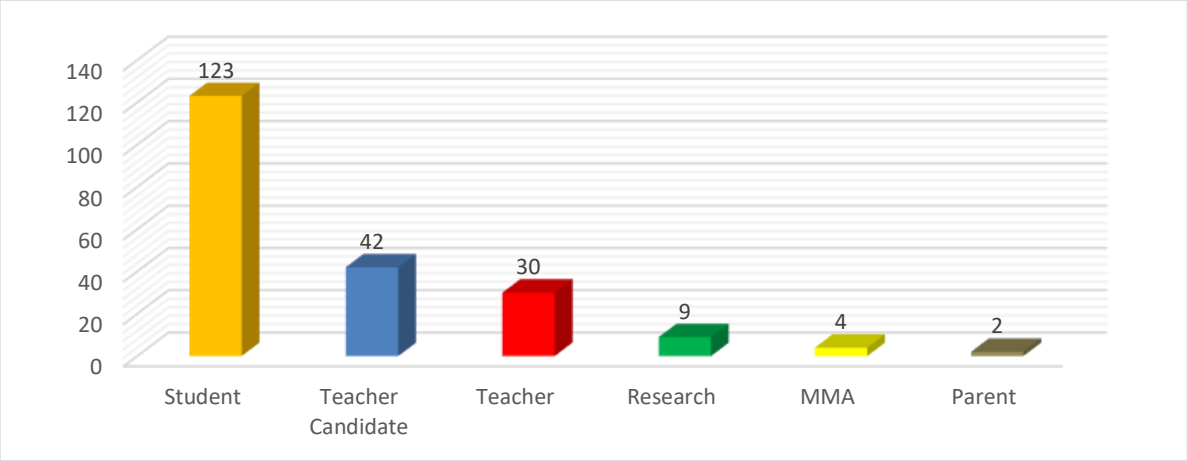


Figure 15. Distribution of theses on mathematical modeling by sample

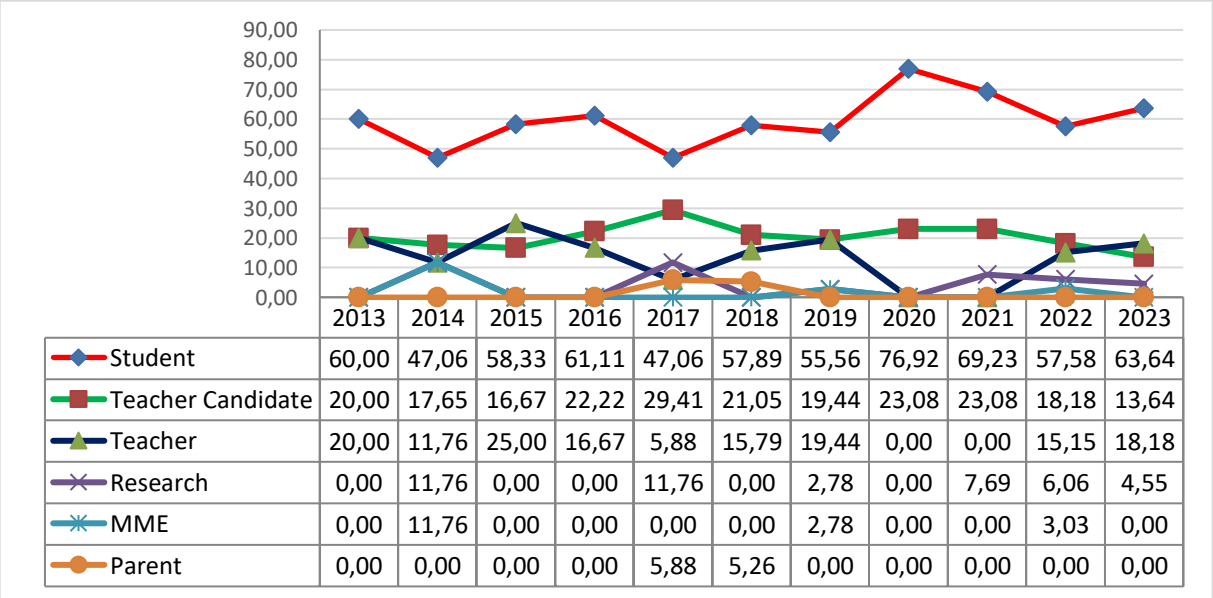
Table 14 and Figure 15 show the change of theses over the years according to sample types.

Table 14. Mathematical modeling changes of theses according to sample types in terms of years

Sample Type	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Sum*
Student	6	8	7	11	8	11	20	10	9	19	14	123
Teacher Candidate	2	3	2	4	5	4	7	3	3	6	3	42
Teacher	2	2	3	3	1	3	7	0	0	5	4	30
Research	0	2	0	0	2	0	1	0	1	2	1	9
MMA	0	2	0	0	0	0	1	0	0	1	0	4
Parent	0	0	0	0	1	1	0	0	0	0	0	2

*Since some studies work with more than one sample group, the total number is more than the number of studies.

Table 14 expresses the distribution of the sample types used in the theses by year. The sample of students reached 20 theses in 2019 and was used in a total of 123 theses. Teacher candidates were included in 5 theses in 2017 and took part in a total of 42 theses, and in 2019, they were included in 7 theses and reached the highest utilization rate. The sample of teachers was included in a total of 30 theses, and in particular, it was used in 7 theses in 2019. The research sample from other sample types was included in a total of 9 theses, and an increase was observed in this type in 2014 and 2022. The MMA sample was used in only 4 theses, the use of this type was mostly seen in 2014 and 2022. On the other hand, the parent sample was rarely preferred and was used in only 2 theses in total, and it was included in one thesis each in 2017 and 2018.



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Student	60,00	47,06	58,33	61,11	47,06	57,89	55,56	76,92	69,23	57,58	63,64
Teacher Candidate	20,00	17,65	16,67	22,22	29,41	21,05	19,44	23,08	23,08	18,18	13,64
Teacher	20,00	11,76	25,00	16,67	5,88	15,79	19,44	0,00	0,00	15,15	18,18
Research	0,00	11,76	0,00	0,00	11,76	0,00	2,78	0,00	7,69	6,06	4,55
MME	0,00	11,76	0,00	0,00	0,00	0,00	2,78	0,00	0,00	3,03	0,00
Parent	0,00	0,00	0,00	0,00	5,88	5,26	0,00	0,00	0,00	0,00	0,00

Figure 16. Distribution of theses on mathematical modeling in terms of years according to sample types

The most frequently used sample type in theses is students with 58.57%. This situation can be explained by the fact that the target audience of educational research is generally student groups. In addition, this finding reveals the importance of student-centered studies to develop educational policies and teaching strategies. This finding is in line with the research results of Albayrak (2017), Koç (2020) and Eryiğit (2022). The fact that 20.00% of teachers and 14.29% of teacher candidates are preferred shows that the role of teaching staff in education processes should be investigated more. The increase in the use of teachers and teacher candidates as a sample over the years shows that there is an increasing interest in how teaching processes can be improved.

Table 15 show the sample distributions according to the teaching levels in which the theses are concentrated.

Table 15. Distribution of theses on mathematical modeling according to the levels of education in which they are concentrated

Variable	Level	Number (n)	%
Teaching Level	Secondary school	91	46,19
	High school	50	25,38
	University	21	10,66
	Primary school	10	5,07
	Multiple Tiers*	25	12,69
Sum		**197**	**100,00**

* Studies independent of stages or with more than one stage

Table 15 shows the distribution of theses according to teaching levels. Most of the theses are concentrated at the secondary school level, with 91 theses (46.19%) constituting the highest rate. This is followed by 50 theses at the high school level (25.38%) and 21 theses at the university level (10.66%). While 10 theses (5.07%) were made at the primary school level, the number of theses covering more than one level was recorded as 25 (12.69%).

In Table 16, the distribution of theses according to the grade levels in which they are concentrated is presented.

Table 16. Distribution of theses on mathematical modeling according to the grade levels in which they are concentrated

Variable	Class	Number (n)	%
Teaching Level/Class Information	Grade 2	2	1,02
	Grade 4	8	4,06
	Grade 5	10	5,08
	Grade 6	23	11,68
	Grade 7	37	18,78
	Grade 8	21	10,66
	Grade 9	18	9,14
	Grade 10	17	8,63
	Grade 11	15	7,61
	Pre-service teachers	21	10,66
	Multiple classes	25	12,69
Sum		**197**	**100,00**

According to Table 16, the highest number of studies were done at the 7th grade level (18.78%), followed by the 8th grade (12.69%) and 6th grade (11.68%), respectively. The least work was carried out at the 2nd grade level (1.02%). In addition, a significant density (10.66%) was observed in studies covering more than one class of theses. In general, there is a significant concentration of theses on the middle school level grades, especially in the 7th and 8th grades. According to the education levels, the fact that the theses are made at the secondary school level can be associated with the fact that this period is a critical transition period in terms of education. Considering that the middle school period is a period in which students reinforce their basic academic skills and develop more abstract thinking skills, it is expected that more research will be done at this stage (Demirbilek, 2022). Although 25.38% of theses at the high school level and 10.66% at the university level indicate that research decreases with the increase in the level of education, research progress can be expanded by increasing research opportunities for these levels. Information on the sample size of the theses related to mathematical modeling prepared in the field of mathematics education is presented in Table 17 and Figure 16.

Table 16. Information on the sample size of theses related to mathematical modeling

Variable	Sample Size	Number (n)	%
Sample Size Ranges	0-10	20	10,15
	11-20	33	16,75
	21-30	49	24,87
	31-40	18	9,14
	41-50	11	5,58
	51-60	20	10,15
	61-70	16	8,12
	71-100	12	6,09
	101-200	10	5,08
	201 and above	8	4,06
Sum		**197**	**100,00**

Table 17 shows the distribution of theses in relation to sample sizes. According to the data, the most common sample group range is between 21-30 and stands out with a rate of 24.87%. This is followed by studies with a sample size between 11-20 with 16.75%, 0-10 with 10.15% and 51-60. Studies with a sample size of 201 and above are represented at the lowest rate (4.06%). In general, the majority of theses have focused on sample sizes up to 30, with a certain increase in the range of 51-60. Studies with larger samples are limited.

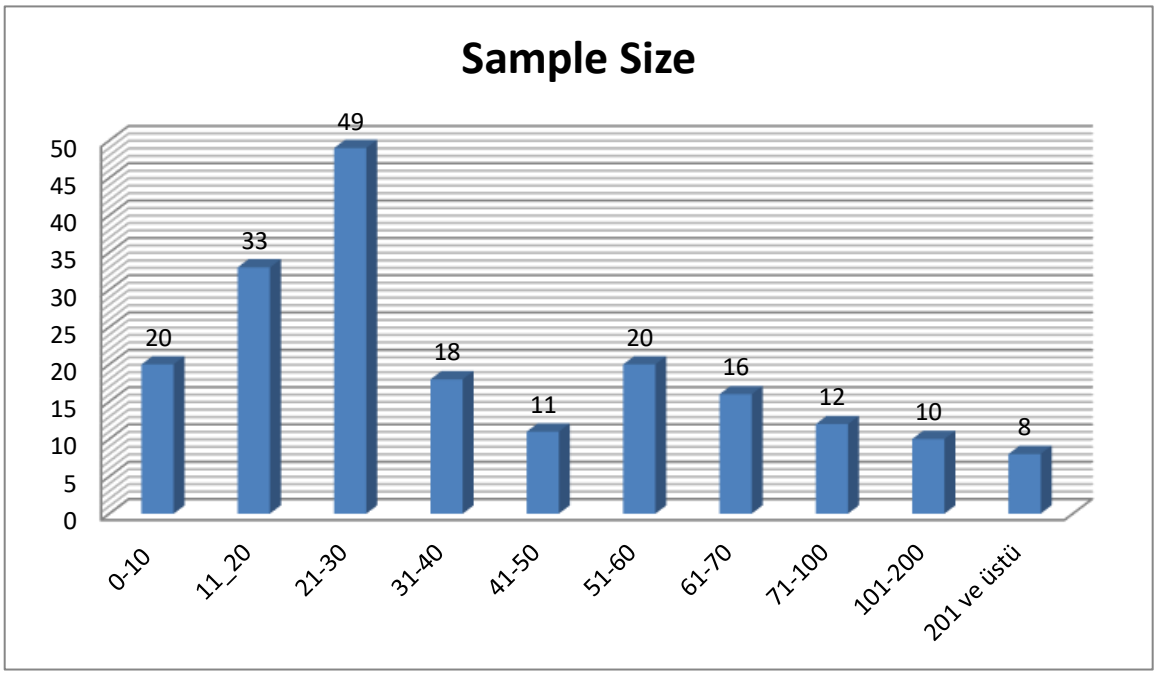


Figure 17. Distribution of theses related to mathematical modeling according to sample size

In the distribution according to sample sizes, the fact that samples in the range of 21-30 are the most common range with a rate of 24.87% shows that it is more appropriate and manageable in small-scale, experimental or action research. The examination of small groups, especially in research in the field of teaching, makes it easier to observe the learning processes of individuals in more detail. The fact that an increase in the range of 51-60 is prominent because it is the level at which more large-scale research has begun. However, the low preference (4.06%) of sample sizes of 201 and above shows that large-scale studies are less preferred due to reasons such as limited resources and time. Reasons such as the fact that researchers trying to reach this number with standardized tests face obstacles in accessing more sample groups, the inconsistency of student responses in revealing relationships, or the fact that such studies do not provide the opportunity to examine in depth can be given as reasons for the low number of high-sample group studies.

The distribution of the studies according to the data collection tools is another sub-research question. In Table 18 and Table 19, the findings of the data collection tools of the theses related to mathematical modeling prepared in the field of mathematics education are presented.

Table 18: Findings of data collection tools used in theses on mathematical modeling

Variable	Tools	Number (n)	%
Data Collection Tools	Interview form	123	37,39
	Audio and video recording	55	16,72
	Observation form	54	16,41
	Likert-type scale	25	7,60
	Written document	19	5,78
	Academic achievement test	18	5,47
	Worksheets	12	3,65
	Rubric	11	3,34
	Daily	8	2,43
	Structured girid	4	1,22
Sum		**329**	**100,00**

Table 18 presents the distribution of data collection tools used in theses. The most frequently used data collection tool was the interview form with 37.39%. Audio and video recordings rank second with a representation of 16.72%. Observation forms come third with 16.41%. Among

other data collection tools, Likert-type scale (7.60%), written documents (5.78%), academic achievement test (5.47%), worksheets (3.65%), rubric (3.34%), diary (2.43%) and structured grid (1.22%) were less preferred. In general, it is seen that qualitative data collection tools are more widely used in dissertations. In the use of data collection tools, the use of the interview form as the most common tool reflects the interest of researchers in qualitative data. The fact that interview forms are frequently preferred in order to obtain in-depth information and to evaluate the opinions of the participants in more detail can be considered as a result of the widespread use of qualitative research. The names of the standard data collection tools and the information about the researchers who developed them are presented in Table 4.19.

Table 19. Names of standard data collection tools and information about the researchers who developed them

Scale Name	Researcher	Number (n)
Mathematical Modeling Self-Efficacy Scale	Koyuncu et al. (2016)	6
Mathematical Modeling Self-Efficacy Scale	Stohlmann and Yang (2021)	3
Mathematical Modeling Attitude Scale (MMTS)	Demir et al. (2023)	3
Mathematical Modeling Skill Test	Lesh and Doerr (2003)	3
Mathematical Association Self-Efficacy Scale	Özgen and Bindak (2018)	3
Modeling Competency Assessment Rubric	Lesh and Doerr (2003)	3
Reading Comprehension Skills Test	Karabay (2015)	3
Scale for Determining Mathematical Literacy Achievement Level	PISA (OECD, 2012)	3
Problem Solving Skill Test Scoring Ruler	Silver and Cai (1996)	3
Conceptual/Transactional Approach to Problem Solving Belief Scale	NCTM (National Council of Teachers of Mathematics)	
Mathematical Problem Solving Attitude Scale	Zan and Martino (2007)	3
Technological Pedagogical Domain Knowledge Scale	Schmidt et al. (2009)	3
Critical Thinking Skill Test	Ennis and Weir (1985)	2
Attitude Towards STEM Scale	Freitag et al. (2014)	2
STEM Motivation Scale	Kier et al. (2014)	2
Critical Thinking Tendency Scale	Facione (1990)	2
Visual Literacy Self-Efficacy Perception Scale	İlhan et al. (2018)	2
Scientific Epistemological Beliefs Scale	Conley et al. (2004)	2
Mathematics Attitude Scale	Aiken (1974)	2
Mathematics Belief Scale	Schoenfeld (1989)	1
Problem Solving Skill Determination Scale (PCSS)	Heppner and Petersen (1982)	1
Van Hiele Geometry Test	Van Hiele (1957)	1

Table 19 shows the standard data collection tools and the researchers who developed these tools. Scales and tests for different skills such as mathematical modeling, problem solving, attitude and self-efficacy stand out. The Mathematical Modeling Self-Efficacy Scale developed by Koyuncu et al. (2016) is the most frequently used data collection tool in theses. In addition, the Mathematical Modeling Self-Efficacy Scale developed by Stohlmann and Yang (2021) for the same purpose has been frequently used in research. In addition, the Mathematical Modeling Attitude Scale (MMTÖ) was introduced to the literature by Demir et al. (2023), the Mathematical Association Self-Efficacy Scale by Özgen and Bindak (2018) and the Mathematical Modeling Skill Test by Lesh and Doerr (2003) and are frequently used in theses. It is seen that data collection tools for various skills such as critical thinking, STEM motivation and visual literacy are also included in the table.

It can also be supported by the finding of Aztekin and Taşpınar-Şener (2015) that descriptive analysis research is prominent in mathematical model and modeling studies. Among the quantitative analysis methods, the dependent sample t-test stands out as the most frequently used method with a rate of 7.37%. This suggests that research is generally aimed at examining

the effect of changes on the same sample. The use of the independent sample t-test at a rate of 6.09% reveals that there is an interest in making comparisons between different groups, but such studies are not as common as qualitative studies.

The fact that the Mathematical Modeling Self-Efficacy Scale developed by Koyuncu et al. (2016) is the most widely used among standard data collection tools shows that this scale is widely accepted in the academic environment in terms of both its validity and reliability. The frequent use of this scale may also be due to its methodological approach to measuring mathematical modeling abilities. Mathematical modeling includes students' ability to express and solve real-world problems in mathematical terms (Hıdıroğlu and Güzel, 2013); Thus, the widespread acceptance of a scale that can accurately assess these skills emphasizes the importance of this skill in education. Since the concept of self-efficacy refers to individuals' beliefs about accomplishing a specific task, the use of this scale stands out as a critical tool in understanding students' confidence and motivation in mathematical modeling (Arseven, 2016). The prominence of scales for different skills developed by Stohlmann and Yang (2021), Demir et al. (2023), Özgen and Bindak (2018), and Lesh and Doerr (2003) may be based on the fact that they are more effective in different cultural contexts or different groups of students, or that they focus on different aspects of mathematical modeling competence. The data collection tool of Demir et al. (2023) has adapted the scale to modern educational settings to include current educational approaches and technological integration. This diversity allows researchers and educators to have more comprehensive and flexible tools when assessing students' mathematical modeling abilities. The use of these data collection tools also increases the methodological richness and depth in mathematics education research. Data collection tools allow researchers to tailor their work to more specific research questions or hypotheses. It also reflects how scales have evolved over time, shifts in educational theories, and transformations in student needs.

Distribution of theses according to the data analysis used It is presented in Table 20.

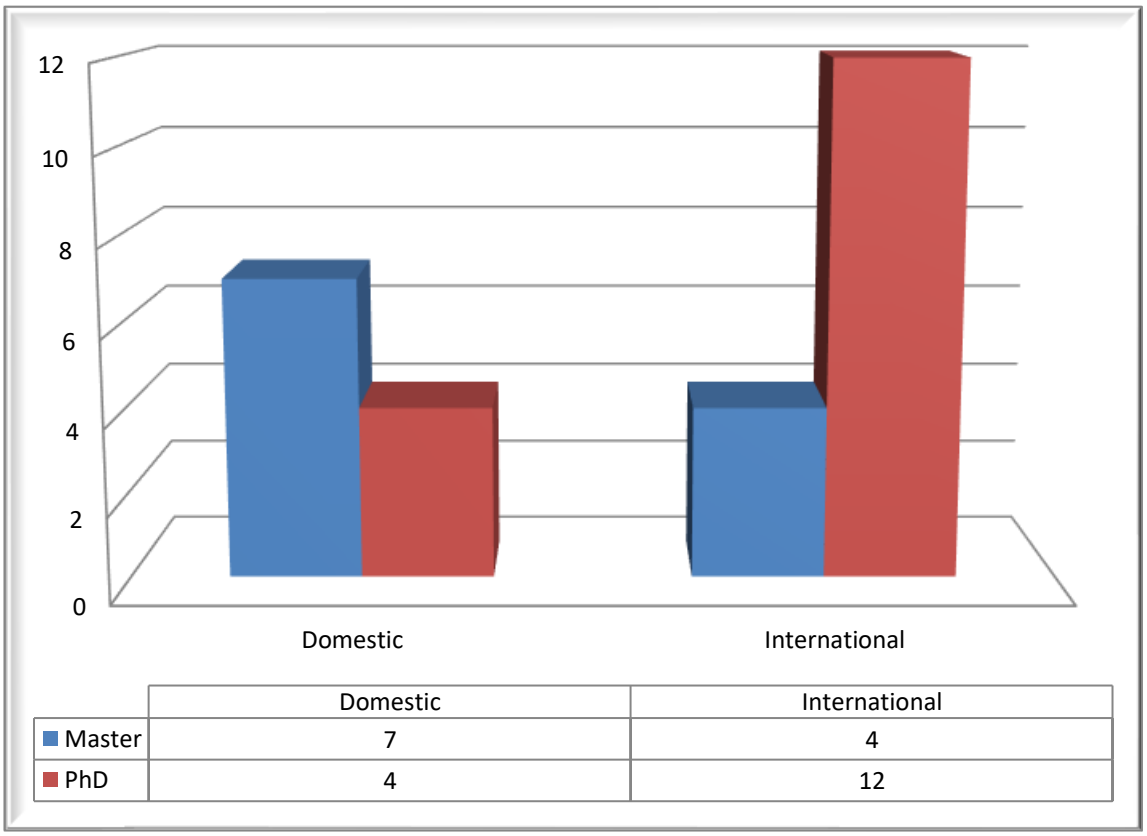
Table 20. Distribution of the types of data analysis used in the theses

Analysis Type	Analysis	Number (n)	%
Qualitative Analysis Techniques	Content analysis	102	32,69
	Descriptive analysis	68	21,79
	Thematic analysis	6	1,92
	Grounded theory	3	0,96
	Discourse analysis	3	0,96
	Meta-synthesis (thematic content analysis)	3	0,96
	Document analysis	2	0,64
Quantitative Analysis Techniques	Dependent sample t-test	23	7,37
	Independent sample t-test	19	6,09
	ANOVA	14	4,49
	Mann Whitney U test	14	4,49
	Wilcoxon Signed Ranks Test	12	3,85
	ANCOVA	10	3,21
	Simple Linear Correlation Test	6	1,92
	Pearson Correlation Test	6	1,92
	Meta-analysis	5	1,60
	Multiple linear regression	4	1,28
	Spearman's Rho correlation test	4	1,28
	Structural equation model	3	0,96
	Bidirectional ANOVA	3	0,96
	Kruskal Wallis H test	2	0,64
Sum		**312**	**100,00**

Table 20 presents the distribution of data analysis types used in theses. Among qualitative analysis techniqu

es, content analysis is the most commonly used method with 32.69% (n=102). Descriptive analysis ranked second with 21.79% (n=68), while thematic analysis was used at a rate of 1.92% (n=6). In qualitative analysis, other techniques such as embedded theory, discourse analysis, meta-synthesis and document analysis were also preferred at low rates. Among the quantitative analysis techniques, dependent sample t-test was the most commonly used method with 7.37% (n=23) and independent sample t-test was used at a rate of 6.09% (n=19). ANOVA and Mann Whitney U test were used at equal rates with 4.49% (n=14), while other techniques included Wilcoxon Signed Ranks Test (3.85%, n=12%), ANCOVA (3.21%, n=10) and correlation tests. This distribution shows that both qualitative and quantitative analysis methods are applied in a wide range of research. The fact that content analysis is the most common method in the distribution of qualitative analysis methods at a rate of 32.69% shows that it is at the forefront in parallel with data collection tools. The use of descriptive analyses at a rate of 21.79% indicates that a more general approach has been adopted in data interpretation.

The type of technology used in the mathematical modeling activities in the theses and their distribution according to the thesis types are presented in Figure 23 and Table 21.



	Domestic	International
Master	7	4
PhD	4	12

Figure 18. Distribution of technology uses in mathematical modeling activities in theses according to thesis types

Figure 23 shows the distribution of the use of technology in mathematical modeling activities according to thesis types. The use of technology is 7 in master's theses and 4 in doctoral theses. The use of technology is seen as 4 in master's theses and 12 in doctoral theses abroad. These data show that the use of technology in doctoral dissertations abroad is more common.

Table 21. Distribution of the types of technology used in the theses

Variable	Tools	Number (n)	%
Use of Technology	GeoGebra	4	14,81
	Video-based	4	14,81
	Computer-aided	3	11,11
	Video supported	2	7.41
	Online communication applications	2	7,41
	Microsoft Teams online	2	7,41
	Calculator with function	1	3,70
	Web 2.0 tools	1	3,70
	Robotics	1	3,70
	LoggerPro 3	1	3,70
	Computer algebra systems (CAS)	1	3,70
	C.H.I.C. (Implicative and Cohesive Hierarchical Classification) software	1	3,70
	Scratch	1	3,70
	TI-Nspire	1	3,70
	Desmos	1	3,70
	TinkerPlots	1	3,70
Sum		**27**	**100,00**

According to Table 21; When we look at the technology tools commonly used in theses, GeoGebra and video-based technologies come to the fore with a rate of 14.81%. These tools have been used 4 times in mathematical modeling theses. Computer-aided technologies have been included in three theses, and tools such as video-assisted and online communication applications have been used twice in theses. Other technologies, such as Microsoft Teams, Logger Pro 3, Scratch, TI-Nspire, Desmos, Tinker Plots, Web 2.0 tools, and robotics, were favored at lower rates.

Findings on the use of technology in theses reveal significant differences at the master's and doctoral levels both in Turkey and abroad. It has been observed that the use of technology is more common in master's theses (7%) and limited in doctoral theses (4%) in Turkey. This situation brings to mind the idea that the reason for the greater emphasis on the use of technology at the graduate level is the focus on more applied studies at this level. In doctoral theses, it is possible that the use of technology will be more limited as more focus can be placed on theoretical research. When the researches abroad are examined, it is noteworthy that the use of technology in doctoral theses is more common (12%) than in master's theses. This difference shows that doctoral programs abroad offer incentives to conduct more technology-oriented research and technology-related tools are more frequently integrated into research (Akgün, 2020). Among the most widely used technological tools in theses are GeoGebra and video-based technologies with a rate of 14.81%. GeoGebra is a software used for mathematical modeling and visualization and is especially preferred in mathematics education. The widespread use of this software is due to the need for visual concretization of abstract mathematical concepts in education (Arbain and Shukor, 2015). Video-based technologies, on the other hand, are widely used to support visual learning in educational processes and ensure the effective presentation of learning materials (Ay, Karadağ and Acat, 2015).

Computer-aided technologies have been frequently featured in dissertations and have been used especially in the analysis of research data and the development of teaching materials. The use of computers in such studies offers a great advantage in terms of accelerating data analysis and increasing its accuracy (Bilgin, Tatar and Ay, (2012). As an online communication and collaboration platform, Microsoft Teams supports distance learning in education and increases the interaction between students and teachers. The lower use of this platform can be explained by the fact that there is less space for research on distance learning in theses (Martin and Tapp,

2019). LoggerPro 3, on the other hand, is a software for data collection and analysis and is generally used in science education (Fabric, 2021). Scratch is a tool developed for programming and algorithm teaching, while TI-Nspire is a graphing calculator software used for mathematical calculations and data analysis. Less use of these tools may be due to the limited number of theses focused on programming and science. Desmos is used for visualization in mathematics education as an online graphic drawing tool, while TinkerPlots is a software developed for data analysis and statistics teaching (Ay, Karadağ and Acat, 2015).

Web 2.0 tools are online tools that allow students and teachers to produce and share interactive content. The fact that these tools, which are used in education, especially in collaborative learning processes, are included in the theses at lower rates may be an indication of the commitment to classical education methods. Robotic technologies, on the other hand, are used to support learning processes in engineering and STEM fields (Fabric, 2021; Demirel & Turkmen, (2023). The greater prevalence of the use of technology in doctoral dissertations abroad is associated with the greater promotion of technology integration in education in these countries (Martin and Tapp, 2019). In general, the limited use of technology in theses in our country is an indication that technology-integrated mathematical modeling approaches should be increased.

CONCLUSION and RECOMMENDATIONS

The results obtained from the research are presented in this section.

1. *Number of Theses and Distribution by Years:* Between 2013 and 2023, a total of 197 theses were examined in YÖK Thesis and ProQuest databases. A significant increase was observed in the number of theses in 2019 and 2022, and 32 theses were prepared in both years. In 2020 and 2021, there was a decrease in the number of theses. However, in recent years, there has been an increasing trend in the number of theses in the YÖK Thesis database.
2. *Distribution by Country in terms of Thesis Types: The* majority of theses in Turkey are at the master's level, and a total of 113 master's and 31 doctoral theses have been recorded. When examined by years, a significant increase has been observed in master's theses in Turkey; 21 theses were reached in 2019 and 22 in 2022. However, in 2020, this number decreased by 6 theses. In terms of doctoral theses, there was a more limited increase in Turkey, with the highest number of 6 doctoral theses in 2022. In the USA, on the other hand, doctoral dissertations are predominant; 46 doctoral and 6 master's theses were recorded. Especially in 2019, there was an increase in doctoral theses and this number reached 7. Master's theses, on the other hand, have been less studied in the U.S. and have only increased in certain years, with some increases in this area in 2020 and 2022. Only 1 doctoral dissertation was found from Canada.
3. *Distribution of Thesis Research by Universities: Atatürk* University has the highest number of theses on mathematical modeling in Turkey and produced 14 theses with a rate of 9.72%. It is followed by Erzincan Binali Yıldırım University with 10 theses (6.94%) and Gazi University and METU with 8 theses each (5.56%). Anadolu University and Hacettepe University are among the other prominent universities with 7 theses (4.86%), while Marmara University draws attention with 6 theses (4.17%). Among the prominent academicians in the consultancy processes of theses, Prof. Dr. Alper Çiltaş from Atatürk University ranked first with 7 theses, while Prof. Dr. Mehmet Bekdemir from Erzincan Binali Yıldırım University and Prof. Dr. Ramazan Gürbüz from Adıyaman University made significant contributions to the field with 4 theses.
4. The university with the highest frequency of mathematical modeling dissertations in the U.S. and Canada is Columbia University, with 8 dissertations and a rate of 15.09%. The Ohio State University ranked second with 5 theses, while North Carolina State University, Purdue University, Ohio University and University of Missouri were the other universities that contributed in this field with 2 theses each (3.77%). Among the prominent advisors in the USA and Canada, Dr. Bruce Vogeli from Columbia University

ranked first with 5 theses, followed by Dr. Azita Manouchehri from The Ohio State University with 4 theses. In the analysis of thesis citations, Dr. Bruce Vogeli stood out as the most cited researcher in this field.

5. *Distribution and Change of Subjects by Years:* The most common issue in the distribution of mathematical modeling topics was the development of modeling activities with 45 studies. This is followed by teaching with 34 studies and mathematical modeling with 27 studies. Other important topics include technology-assisted mathematical modeling (21 studies), tutorial training (20 studies), the use of mathematical modeling as a mathematics teaching tool (19 studies), and big data analysis (18 studies), while concept analysis has received less attention and has been addressed in only 8 studies.
6. Looking at the distribution by year, the issue of developing modeling activities has been studied regularly throughout all years and has been addressed in high numbers, especially after 2018. The subject of teaching, on the other hand, has shown increasing interest since 2017 and reached the highest number (6 theses) in 2023. On the other hand, while there were no theses in 2019, it remained between 2-4 theses on average in other years. This field occupies an important place with a total of 20 theses.
7. Technology-supported mathematical modeling stands out with a total of 21 theses. The subject of big data analysis has increased since 2017 and especially in recent years (2021-2023), it has contributed with 3 theses every year and produced a total of 18 theses. Mathematical modeling as a teaching tool in mathematics has gained traction since 2017 and has been the subject of constant interest for the last three years, with 3 theses each year; A total of 19 theses were produced. The use of mathematical modeling attracted high attention, especially between 2019 and 2022, and reached a total of 27 theses. Concept analysis has been less studied compared to other topics and has only been addressed in a few studies in certain years.
8. According to the results; In the distribution of learning areas, it was seen that the subject of "Numbers and Operations" was the most studied area and a total of 58 theses were produced in this field. This is followed by "Algebra" with 34 theses, with other fields receiving less attention. 16 theses in the field of "Geometry and Measurement", 11 theses in the field of "Probability" and 10 theses in the field of "Data Processing" were registered.
9. Between 2013 and 2023, the most studied topic in the learning fields is "Numbers and Operations", which is regularly studied every year, and especially in 2023, 11 theses were carried out in this field. "Algebra" ranks second with 34 theses and reached the high number of theses in 2019 and 2023. 16 theses were produced in the field of "Geometry and Measurement", and this topic was further studied in 2014 and 2022. The field of "Data Processing", on the other hand, was examined less with a total of 10 theses and interest decreased after 2018. The field of "probability" was also limited to 11 theses and attracted more attention, especially in 2016 and 2022.
10. *Distribution and change of research methods over the years*: According to the results of the research, the most common method in theses is qualitative research with 121 theses with a rate of 61.42% and was used in a total of 118 theses. While qualitative research was the most preferred with 19 theses in 2019, this number increased to 21 in 2022. The least used years are 2013 and 2015; During these years, it was applied in only 7 theses. While the mixed method was included in 49 theses with a rate of 24.87%, it reached the highest level with 11 theses in 2019 and decreased in 2020-2021. Quantitative research is the least preferred method with a rate of 13.71%; While it was not used at all in 2015, it has been featured in 5 and 3 theses in 2022 and 2023, respectively.
11. In the distribution of research models, the case study was the most common model with 59.39% and was used in 117 theses. This model reached the highest levels of utilization in 2019 and 2022, with 20 and 21 theses, respectively. The experimental study ranked

second with a rate of 16.24%; Teaching experiment and action research were included in 13 theses with a rate of 6.60%. The survey model is limited to a total of 11 theses, while other models (meta-analysis, document analysis, design-based model) are rarely used.

12. *When the distribution and changes of the sample types by years are examined* , the most common sample type is students with 58.57% and it is included in a total of 123 theses. The sample of pre-service teachers ranked second with a rate of 20.00%, and teachers took part in 30 theses with a rate of 14.29%. Other sample types were used at lower rates; The research sample was preferred by 4.29%, the MMI sample by 1.90% and the parent sample by 0.95%.

13. When the distribution by years is examined, the student sample was used the most with 20 theses in 2019. Teacher candidates started with 5 theses in 2017 and reached 7 theses in 2019. The sample of teachers took part in a total of 30 theses and came to the fore with 7 theses especially in 2019. While the research sample was used in a total of 9 theses, the MME sample was included in only 4 theses, and the parent sample was rarely preferred and was observed in only 2 theses.

14. *When the distribution of theses according to education levels is examined*, the secondary school level has the highest rate with 91 theses with 46.19%. There are 50 theses (25.38%) at the high school level and 21 theses (10.66%) at the university level. While 10 theses (5.07%) were made at the primary school level, 25 (12.69%) theses covering more than one level were recorded.

15. *According to sample sizes* , the most common range is 21-30, with a rate of 24.87%; Most theses have focused on sample sizes up to 30. An increase in the range of 51-60 is observed, while samples of 201 and above are represented at the lowest rate (4.06%).

16. *The results of the research show that the most frequently used data collection tool in these*is the interview form with 37.39%. This is followed by audio and video recordings with 16.72% and observation forms with 16.41%. Among other tools, qualitative data collection tools such as Likert-type scale (7.60%), written documents (5.78%) and academic achievement test (5.47%) were less preferred.

17. Among the standard data collection tools, the Mathematical Modeling Self-Efficacy Scale developed by Koyuncu et al. (2016) is the most widely used. In addition, scales developed by Stohlmann and Yang (2021), Demir et al. (2023), Özgen and Bindak (2018), and Lesh and Doerr (2003) are frequently included.

18. *Among the qualitative analysis methods*, the most common was content analysis (n=102) with 32.69%, while descriptive analysis was the second with 21.79% (n=68). Thematic analysis was used at a rate of 1.92% (n=6). Other qualitative analysis techniques, embedded theory, discourse analysis, meta-synthesis and document analysis were preferred at low rates.

19. *In quantitative analysis methods, the dependent sample t-test* was the most commonly used method with 7.37% (n=23); independent sample t-test followed by 6.09% (n=19). ANOVA and Mann Whitney U test were used equally at a rate of 4.49% (n=14). Other techniques include the Wilcoxon Signed Ranks Test (3.85%, n=12%), ANCOVA (3.21%, n=10), and correlation tests.

20. *Use of Technology in Theses:* According to the results of the research, the use of technology in master's theses and 4 in doctoral theses was determined as 7 in the country. Abroad, the use of technology was observed as 4 in master's theses and 12 in doctoral theses. The results show that the use of technology in doctoral dissertations abroad is more common.

21. Among the most widely used technological tools in theses are GeoGebra and video-based technologies with a rate of 14.81%. While computer-aided technologies were included in

the theses, tools such as Microsoft Teams, LoggerPro 3, Scratch, TI-Nspire, Desmos, TinkerPlots, Web 2.0 tools and robotics were used at lower rates.

According to the results of the research, suggestions were presented to the relevant stakeholders.

Suggestions for Researchers;

1. Since the upward trend of mathematical modeling theses in mathematics education continues, it is recommended to regularly follow the current number of theses in YÖK Thesis and ProQuest databases.
2. In Turkey, more studies on mathematical modeling in mathematics education should be encouraged in doctoral theses along with master's theses.
3. It is recommended that studies should be continued in universities where mathematical modeling theses are made in mathematics education, especially in leading universities such as Atatürk University, Erzincan Binali Yıldırım University, Gazi University and METU, and that doctoral students and researchers benefit from the knowledge in these universities.
4. For young researchers, it may be recommended to benefit from the experiences of academicians who stand out in this field and have consultancy experience.
5. Cooperation opportunities with prominent universities and consultants in the USA can be explored.
6. It may be recommended to conduct more studies on mathematical modeling issues, especially on topics such as developing modeling activities, teaching, technology-supported modeling and big data analysis, which have attracted high attention in recent years.
7. Due to the dominance of qualitative research and case study model in research methods, it may be recommended to increase the use of quantitative and mixed methods.
8. Due to the high concentration of students in the sample types, it may be recommended to focus on studies with teachers and teacher candidates.
9. In addition to the widespread use of interview forms in data collection tools, scale development and increasing the use of standard scales may be recommended.
10. In the use of technology, it may be recommended to encourage the use of more technological tools and software, especially in doctoral dissertations.

Advice for Teachers

1. He should prepare problems in accordance with the principle of reality.
2. It may be suggested that they integrate different modeling techniques and methods into the teaching process.
3. It may be suggested that students divide into small groups and organize discussions and problem-solving activities.
4. They are required to relate mathematical concepts to examples of daily life.
5. They may be advised to enrich their modeling processes by using digital tools and software.
6. It may be suggested that students encourage them to question assumptions and interpret conclusions.
7. They may be offered step-by-step guidance in the problem-solving process.

8. They are required to design activities according to the interests of the students and increase motivation.
9. Interdisciplinary connections can be established by integrating mathematical modeling with other courses in mathematics education.
10. Teachers should encourage students to collect and measure data.
11. They may be advised to tailor the activities to the needs of the students and the subjects they are struggling with.
12. They may be advised to use real-life problems in modeling activities.
13. It may be recommended to organize informative meetings or seminars to increase the awareness of students and parents about the importance and benefits of mathematical modeling in mathematics education.

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