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The Content Analysis of Mathematical Modelling Studies in Turkey: A Meta-synthesis Study

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Abstract

Researchers expect better utilization in programs and a wider role in guiding future studies from the increasing number of studies carried out on mathematical modeling in recent years. Thus, systematic summary information is presented by descriptive content analysis of research about mathematical modeling in the field of mathematics education in Turkey. Afterwards, the studies were interpreted with a meta-synthesis (thematic content analysis) method from a critical perspective. In conclusion, it was found that mathematical modelling studies in Turkey have not yet reached adequate levels of scope and diversity and most of the studies are merely case studies or experimental studies investigating the effects of mathematical modeling. In Turkey, mathematical modeling is generally considered in the studies as a means to teach mathematics pedagogical objectives are mainly an area of consideration predominantly for researchers. Mathematical modeling has been applied mostly within the context of activities in the educational or contextual perspective. Finally, some suggestions were presented for future studies. The researchers proposed that to benefit more from mathematical modeling studies, (1) more empirical studies should be conducted, (2) more studies should be conducted in secondary and high schools and (3) researchers should give sufficient details about how the teaching was conducted using mathematical modelling.

Keywords

Mathematical modelling
Modeling Approaches
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Content analysis
Meta- synthesis

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Introduction

One of the generally accepted important goals of mathematics teaching is educating individuals who will acquire the competencies and the ability to apply mathematics in their daily lives (Kaiser, 2004). Many recent studies have focused on mathematical modellıng when applied to different class levels (English & Watters, 2004; Kaiser, 2006; Mousoulides, Sriraman, & Christou, 2007; Blum & Borromeo Ferri, 2009). The primary motive for mathematical modelling studies is the opinion that the usage of modelling in schools will provide teaching highly-literate individuals in math who make sense of mathematics through making real-life connections (Erbas et al., 2014).

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Mathematical modelling concept has been a cornerstone of the international surveys that construct the framework for mathematics, in particular with regard to the Programme for International Student Assessment (PISA). Mathematical modelling shares many common key components with the mathematical literacy concept that is frequently emphasized within the PISA framework. The Mathematical literacy concept, which is defined as `an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts`, also emphasizes modeling processes. Furthermore, mathematical modelling has been adopted as a specific area/field in the literature within many studies which have been submitted at congresses organized by the International Commission on Mathematical Instruction (ICMI) and the International Community of Teachers of Mathematical Modelling and Applications (ICTMA).

During the past decade, an increased awareness has arisen regarding mathematical modelling and an increasing number of mathematics education researchers have begun focusing on mathematical modelling in Turkey. This situation has also brought about changes in the Turkish mathematics programs, as has been the case in other countries (MoE Singapore, 2007; CCSSI, 2010). The importance of constructing teaching environments based on mathematical modelling is emphasized within the school curriculum and mathematical modelling is defined as a dynamic methodology which provides a way of recognizing relationships in the nature of problems more easily, by representing a situation mathematically, classifying, generalizing and reasoning (MONE, 2013). Although the requirement for using mathematical modelling in classes is frequently emphasized (National Council of Teachers of Mathematics [NCTM], 1989; 2000; Talim ve Terbiye Kurulu Başkanlığı [TTKB], 2011, 2013), it is not possible to say there is a single view that is agreed upon among educators. Mathematical modelling is also a widely used term in different fields such as engineering, applied mathematics etc. and it is even treated with different purposes and perspectives in mind in mathematics education (Akt. Erbaş et al., 2014; Kaiser, Blomhoj and Sriraman, 2006; Niss, Blum and Galbraith, 2007).

Mathematical Modelling

Modeling is a widely-used term in different disciplines and it is defined as a process of constructing a prototype of an object or a situation from daily life (Erbaş et al., 2014). Modeling refers to a process of constructing a physical, symbolic or abstract model while model refers to the product at the end of the process (Sriraman, 2006). In the literature, mathematical modelling is generally defined as the process of representing real-life situations mathematically (Blum, 1993; Gravemeijer, 2002; Barbosa, 2003; Ferri ve Blum, 2009). The following simplified view (Figure 1) shows the process of mathematical modelling which can be defined by more complex cyclical models (Ferri, 2006).

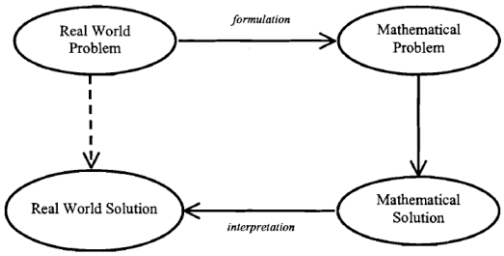


Figure 1. A view of the mathematical modelling process (Cheng, 2001)

Mathematical modelling brings children from basic problem solving, that is making sense of symbolically defined word problems to authentic real-life situations. It is required to define and interpret these situations mathematically (Lesh, 2001). The properties involved such as high- level cognitive processes, the fostering of students' creativity etc. distinguish mathematical modeling applications from traditional word problems (Mousoulides, Sriraman ve Christou, 2007). Many studies have been conducted that compare the processes of solving traditional word problems and

solving more open ended and practical problems which involve mathematical modeling (Blum & Niss, 1991; Verschaffel, 1999; Mousoulides, Sriraman ve Christou, 2007; Lesh ve Zawojewski, 2007).

Mathematical Modeling Perspectives

It is not possible to define a single common perspective for using modeling in mathematics education. Moreover, there have not been enough studies conducted on systematic and detailed analysis of different theoretical perspectives that have emerged in mathematical modelling studies (Erbaş et al., 2014). In this context, Kaiser and Sriraman's (2006) study on classifying modeling perspectives is an important one, which is based on math education studies in the activities of ICMI and ICTMA. It is a more comprehensive study than that seen in past studies, even if the presenting modeling approaches are not distinguished clearly with explicit borders. They presented modelling perspectives under six headings: (i) realistic or applied modeling, (ii) contextual modeling, (iii) educational modeling, (iv) socio-critical modeling, (v) epistemological or theoretical modeling, and (vi) cognitive modeling. These perspectives can be explained in the following way (Kaiser & Sriraman, 2006; Erbaş et al., 2014).

i) The realistic or applied modelling perspective emphasizes solving real world problems and the promotion of modelling competencies for understanding the real world. This perspective considers the pragmatic perspective of Pollak and mathematical modeling that is used to cope with real-life problems in engineering and can be given as an example. A study in this perspective is Kaiser and Schwarz's study (2006), which was carried out with 16-18 aged students and prospective teachers. Kaiser and Schwarz present students with some authentic real life problems proposed by mathematicians working in industry. Each group formed by the students worked independently under the guidance of a prospective teacher. The modelling example was presented by an applied mathematician in the first lecture. One of the modelling examples is as seen below::

Pricing of Air Berlin

Air Berlin sells its flights predominantly using an online booking system via internet, and the prices for the various destinations are not fixed. For each flight the prices are indicated separately and change very often which makes the question arise as to how Air Berlin determines its prices. Analyze the prices and develop an adequate description based on the prices announced on the internet or develop your price system.

(Compiled from Kaiser and Schwarz, 2006)

ii) Contextual modelling emerged from the problem-solving debates in American schools and is related to psychological lab experiments. This perspective focuses on making sense of mathematics. For this purpose, students are expected to deal with real-life situations in which they can use math concepts. It is expected that mathematical modelling will help improve students' problem solving skills. Doerr's case study (2006) conducted with four teachers can be given as an example of this perspective. The study focused on how and to what extent they interpreted students' understanding about exponential functions and how they responded to the students' questions in the classroom environment. It involves problem-solving experiences based on the context of exponential growth and teachers' experiences that engaged their students' development of mathematical models. The following "pennies problem" activity was used in the study:

The Pennies Problem

If you place a penny on the first square of a checkerboard, two pennies on the second square, four on the third square, eight on the fourth square, and so on, how many pennies are on the very last square? A checkerboard is eight by eight squares. Fill in the following table, in which the second column gives the number of pennies on the square whose number is in the first column.

Number of square	Number of pennies
1	
2	
3	
4	
5	
6	

Enter these values in your calculator and plot the points. What patterns do you find in the data? Write an equation that gives the number of pennies as a function of the number of the square. Graph this equation and compare it to your plot of the data points. What is a reasonable domain and range for this function? What is the dollar value of the pennies on the 64th square?

iii) Educational modeling differentiated in a) didactical modeling that emphasizes the structuring and promotion of learning processes and b) conceptual modeling that involves concept introduction and development. This perspective is considered as an integration of realistic and contextual modelling in which pedagogical and subject-related goals are discussed. Most of the approaches in the mathematical modelling researches can be considered under this perspective. To cite some examples, one should mention Maaβ (2006) and Michelsens' (2006) studies. Maaβ focused on the integration of modelling applications into math classes in his empirical study in which she defined modelling competencies. In the other study, Michelsen discussed the function concept within a modelling perspective. A framework for interdisciplinary instruction was developed from the study based on the data obtained from two courses at the university.

iv) The socio-critical modeling perspective emphasizes studies regarding students' critical understanding of their culture and society using mathematics. It focuses on socio-cultural dimensions of mathematics by employing modeling activities. Barbosa (2006), who aimed to outline a socio-critical perspective of modelling in her study, stated that modelling activities in this perspective should have two basic features: " (1) the activity has to be a problem (not an exercise) for the students; (2) the activity has to be extracted from the everyday or other sciences that are not pure mathematics". In his study, Barbosa emphasized the promotion of critical-thinking abilities. One of the activities in his study is the discussion of the following news report. Students were asked to discuss the event in this report.

The News Report

"The bean and corn seeds donated by the Government began to be distributed yesterday afternoon. There are 37.5 tons, 25 tons of bean and 12.5 tons of corn seed. About 8000 subsistence farmers will benefit from this action. According to the mayor, each farmer will receive 3 kg of beans and 2 kg of corn."

v) The epistemological or theoretical modeling perspective emphasizes the investigation of relations between the mathematical concepts or promotion of theory development. Realistic context is less important in the modelling activities which are prepared according to this perspective. For example, in the study of Garcia et al. (2006), that is considered in this perspective, mathematical modelling processes were reformulated from the point of view of the anthropological theory of didactics using mathematical praxeologies. The modelling process concerning "functional relationships" was analyzed in this perspective employed in secondary education.

vi) The final modeling perspective is the cognitive modeling perspective in which the researchers focus on an analysis of students' cognitive processes during modeling and promotion of mathematical-thinking processes. In this perspective, mathematical modeling is considered in the context of cognitive psychology. In the cognitive perspective, Borromeo Ferri's (2006) study can be given as an example that focused on the mathematical modelling process. She specifically emphasized the "modelling cycle under cognitive psychological aspects" in her study that involves discussions and comparisons of modelling cycles in the literature according to distinctions in the cycles' phases.

Kaiser (1995) categorized the mathematical modelling studies into four groups according to their goals. These are a) the studies that have pedagogical goals, and with opportunities for reporting that enable students to understand rea- life situations in a better way; b) the studies which have psychological goals that involve fostering motivation and improvement of attitudes towards mathematics and mathematics teaching; c) the studies which have psychological goals, organizing learning processes and presenting new mathematical concepts and methods and finally; d) the studies which have science-related goals, criticizing the role of mathematics in real-life and presenting sections of the historical development of mathematics.

In the literature, the most comprehensive classification of modelling perspectives was made according to its intended use in mathematics education (Erbaş et al., 2014). In this context two different approaches can be mentione; modeling as the purpose of teaching mathematics and modeling as a method (vehicle) to teach mathematics. The former focuses on teaching mathematical - modelling abilities and strategies, using mathematical knowledge and models in real situations, while the latter focuses on using mathematical modelling process to develop mathematical knowledge and models. The perspective that handles modelling as the purpose of teaching mathematics emphasizes that there must be lessons for modelling techniques and abilities outside math lessons while in the other perspective it is proposed that the mathematics program should involve mathematical modelling studies. These two perspectives were designated as "modelling as content" and "modeling as a vehicle" by Julie (2002).

There are various modelling perspectives which have emerged as theoretical perspectives in the literature and effective in structuring studies. For example, the modeling perspectives defined by "models and the modeling perspective" or Freudenthals' "realistic mathematics education" can be handled separately in the studies that consider modelling as a vehicle. Both of these math education-specific approaches are based on socio-cultural and constructivist theories (Freudental, 1991; Lesh & Doerr, 2003). The models and modeling perspective is a comprehensive theoretical approach describing mathematical teaching, learning and problem-solving. In this perspective modelling problems are presented in the form of model-eliciting activities (Erbaş et al., 2014). In these model-eliciting activities which are guided by certain principles, students are confronted with real-world situations and are expected to construct models and elicit mathematical concepts intuitively. On the other hand, the realistic mathematics education approach aims to develop students' primitive and informal contextual models (model of) that are constructed by investigating real life problems and transform these into formal and more abstract models (model for). The modeling process occurs between these two models (model of and model for) and the goal of obtaining formal models reflects the "emergent modelling" perspective in this theory (Doorman & Gravemeijer, 2009).

The above-mentioned classifications concerning modelling perspectives generally reflect modelling studies in different countries. In the modelling literature, even if it was not defined as a meta-synthesis study, the only study that can be accepted as meta-synthesis is Kaiser and Sriraman's (2006) study concerning modelling perspectives. It involves the thematic analysis of mathematical modelling studies mainly presented in the activities of ICMI and ICTMA. Moreover, the researchers have not seen an interpretive study that synthesizes the relevant attainable modelling studies with a holistic and critical approach by identifying themes and patterns. But there are theoretical studies that discuss basic concepts and different perspectives by providing examples from the studies in the mathematical modelling literature (Kaiser, 1995; Erbaş et al., 2014; Dündar et al., 2012). Also, some of the themes which are used in this study were based on these studies that investigated different dimensions of the relevant subject. The researchers have not seen a meta-synthesis study in the literature that focused on mathematical modelling studies in Turkey. They think that this analysis of increasing number of modelling studies from a holistic perspective will help to guide and serve as an example for other content analyses in other countries regarding mathematical modelling and will render more benefit to educators. There has been a particular emphasis on mathematical modeling in mathematics curricula on account of the idea that it helps the learning of mathematics through facilitating understanding and developing positive attitudes towards mathematics. In this context, this study, that involves the systematic and deep analysis of orientations and perspectives in mathematical modelling studies, will be useful for program developers. On the other hand, all over the world, the use of mathematical modelling in classroom practice and teaching processes is not yet at the desired level (Blum and Ferri, 2009). Informing teachers about fundamental concepts, perspectives and usage of modelling may make modeling a more common occurrence/practice in schools. In conclusion it is thought that this type of study will be useful for program developers and teachers in addition to researchers. Since the literature is not at the desired level in this field (Kaiser et al., 2006) and studies in Turkeyin this field are still in a state of development , it is important to conduct a descriptive analysis of modelling studies and determine the needs for research. Diversifying modelling studies in Turkey by carrying out such research at different class levels and by conducting better quality and more comprehensive studies will indirectly enhance the teaching processes in schools. It is one of the aims of this review to inform researchers about the distribution of modelling studies according to years, sampling and methodology.

Generally, the aim of this study is to determine the present situation of mathematical modelling studies in Turkey using descriptive analysis and meta-synthesis. Within this framework, the descriptive properties of present modelling studies, the perspectives and orientations in these studies were analyzed systematically with respect to fundamental concepts and perspectives in the literature. The thematic classifications, constructed to determine approaches to mathematical modelling studies in Turkey, are explained in the methodology section. According to the aim defined, the following questions will be discussed:

- How are Turkish mathematical modelling studies distributed according to their years, sampling and methodology?
- For which goals and in which ways is mathematical modelling used in modelling studies in Turkey?
- Which modelling perspectives were commonly preferred in the studies?

Methodology

In this study two content analysis techniques were used together. Overall, the data set was gathered and interpreted by organizing this systematically through the identification of certain concepts and themes (Yıldırım and Şimşek, 2005). Firstly, the systematic review of the existing literature about mathematical modelling studies conducted in Turkey was presented through the employment of a a descriptive content analysis, then the studies were interpreted with a critical view through meta-synthesis (thematic content analysis).

Data Analysis

After the descriptive-content analysis of mathematical modelling studies, a meta-synthesis (thematic analysis) was conducted to allow for a deeper interpretation and synthesis of studies (Çalık and Sözbilir, 2014). Since almost all of the analyzed studies were qualitative or mixed-method research that includes qualitative methods, the studies were found to be suitable for thematic analysis. The researchers identified themes and subthemes by making use of the classifications in the literature. These themes are "goal", "usage" and two different types of approaches in the literature; a "general use" and "modelling perspective".

The researchers considering the purposes of mathematical modelling studies in Turkey identified the “goal” theme and this theme was categorized in four sub-themes through reference to from the classifications in the literature. The goals of mathematical modelling studies were classified in four categories using the classification employed by Kaiser (1995); “pedagogical”, “psychological”, “subject-related” and “science-related”. In this classification, the studies that discuss the better teaching of a subject or a concept were analyzed in the “subject-related” category. Since pedagogy is a more general concept that involves the improved teaching of a subject or learning difficulties connected with a subject, unlike Kaiser, the researchers considered all the studies which pursue goals to teach and understand in the “pedagogical” category. The studies that have psychological goals were identified within a “affective” category which was also considered as a separate category by Kaiser (1995). The studies that focus on the understanding of mathematical modelling processes rather than pedagogical and affective goals and aim to analyze cognitive steps in this process were grouped in the “process” category. Finally, the studies that have goals for explaining and developing theories in the literature rather than process were identified within a “theoretical” category.

It was seen that mathematical modelling was applied with model-eliciting activities or problems and rarely was modelling conducted with technology was investigated without taking into account that it is applied with activity or problem. This studies, that differ according to with what and in which environment modelling is used, were categorized according to the “usage” theme. This theme identifies with which components of teaching processes mathematical modelling is used and with which context it is presented.

“General use” and “modelling perspective” themes were explained in the literature. By the “general use” theme, it is aimed to evaluate the studies according to the purpose of or the use of mathematical modelling and by the “modelling perspective” theme, it is aimed to determine in which categories the analyzed modelling studies are identified according to the classification of Kaiser & Sriraman (2006). In the study, unlike Kaiser & Sriraman, an epistemological perspective was identified in a broader range and any theoretical study about mathematical modelling was incorporated into this perspective. Table 1 displays the final matrix constructed by reviewing the themes according to the information obtained from the coding process. The purpose of the matrix is interpreting and synthesizing mathematical modelling studies in Turkey from a critical viewpoint (Çalık and Sözbilir, 2014). The studies were analyzed comparatively according to this matrix.

Table 1. The themes and their short explanations

Themes	Sub-Themes	Explanation
1. Goal	**a)Pedagogical**	goals for learning, teaching and understanding
	b)Affective	the studies that consider affective characteristics like motivation and attitudes towards mathematics
	c)Process	focus on understanding modelling processes
	d)Theoretical	focus on explaining and developing theories in the domain
2. Usage	**a)Activity**	with model-eliciting activities
	b)Problem	with modelling problems
	c)Technology	with using mathematics software
3. General Use	**a)Purpose**	consider modelling as the purpose of mathematics teaching and focus on teaching mathematical modelling
	b) Vehicle	consider modelling as a vehicle used for mathematics teaching and focus on using modelling for promoting students' knowledge and models
4. Modelling Perspective	**a)Realistic**	realistic and applied modelling perspectives, promoting modelling comptencies for understanding real-life, and the solution of real-world problems
	b)Contextual	pursue psychological and subject-related goals, focus on the solution of word problems and making sense of them.
	c)Educational	constructing and developing learning processes, instructive modelling, presenting and developing a concept
	d)Epistemological	theoretical studies related with the domain
	e)Cognitive	analysis of cognitive processes that students experienced during mathematical modelling, focus on developing mathematical thinking processes

Data Gathering

To gather studies, the researchers searched for studies focusing on mathematical modelling in math education that were conducted in Turkey between 2004 and 2014. They did not put any limitation on the sample size and all of the well-qualified studies that adhere to the criteria were incorporated to the analysis. Firstly, the Turkish journals on the databases ERIC, SSCI, SCI and AHCI within the scope of Math Education (Education and Science, Educational Sciences: Theory & Practice, Hacettepe University Journal of Education, Eurasia Journal of Mathematics Science and Technology Education) were searched for. Then the journals on the databases ULAKBİM, ASOS and Google Scholar were searched. Besides searching electronic databases, the researchers looked for the theses related to mathematical modelling from the Council of Higher Education Thesis Center. In looking for the mathematical modelling studies, the researchers entered the keywords "modelleme eğitimi", "matematiksel modelleme", "model oluşturma etkinliği", "modelleme etkinliği", "mathematical modeling", "model eliciting activities" in the above-mentioned databases. When the researchers reached a study available both as a thesis and as an article, the thesis was incorporated to the analysis. They took care to avoid duplication. The following form was used as a data-gathering tool during the coding and the evaluation process of the studies.

Table 2. Forms Used as a Data Gathering Tool

<table>
<tr><td colspan="5">A. IDENTITY OF THE STUDY</td></tr>
<tr><td>NAME</td><td colspan="4"></td></tr>
<tr><td>Authors</td><td colspan="3"></td><td>JOURNAL TYPE</td></tr>
<tr><td>Study Type</td><td colspan="3"></td><td>Year:</td></tr>
<tr><td colspan="5">B. SUBJECT</td></tr>
<tr><td colspan="5">C. AIM</td></tr>
<tr><td colspan="5">D. RESULT</td></tr>
<tr><td colspan="5">E. METHODOLOGY :</td></tr>
<tr><td colspan="2">Qualitative
Action Research ( )
Phenomenology ( )
Case Study ( )
Grounded Theory ( )
Other ( )</td><td colspan="2">Quantitative
Experimental Design ( )
Survey Method ( )</td><td>Mixed Method</td></tr>
<tr><td colspan="2">F. SAMPLE</td><td colspan="2">G. GENERAL USE</td><td>H.MODELING PERSPECTIVE</td></tr>
<tr><td>SAMPLE TYPE
Primary (1-5) ( )
Primary (6-8) ( )
Secondary (9-12) ( )
Undergraduate ( )
Teacher ( )
Graduate ( )</td><td>SAMPLE SIZE</td><td colspan="2">Purpose ( )
Vehicle ( )</td><td>Realistic ( )
Contextual ( )
Educational ( )
Epistemological ( )
Cognitive ( )</td></tr>
<tr><td colspan="2">I.GOAL
Pedagogical ( ) Affective ( ) Process ( )
Theorical ( )</td><td colspan="3">J. USAGE
Activity ( ) Problem ( ) Technology ( )</td></tr>
</table>

Since some studies (3) identified the modelling only by using concrete materials and could not be related to the mathematical modelling concept in the math education literature, they were excluded from the study. Moreover, the proceedings announced in the scientific activities such as symposium and congress were excluded from the study. This is because the researchers found it difficult to categorize the proceedings according to the themes. In order to determine the studies incorporated to the analysis, the researchers used the following criteria:

- The study is related to mathematical modelling in math education.
- The study was published in a peer-reviewed journal
- The study was published during 2004 to 2014.
- The search was performed in June-August 2014.
- The study was conducted in Turkey.
- The research process was reported in sufficient detail.

At the end of the data gathering process, 37 studies were incorporated into the analysis according to the given criteria. The gathered studies and their descriptive properties are presented in the following table.

Table 3. The studies incorporated to the analysis

STUDIES	METHODS									Education Level of Sample	YEAR			
	Action Research	Phenomenology	Case Study	Mixed Method	Experimental Design	Survey Method	Grounded Theory	Theoretical Study	Other		2007-2008	2009-2010	2011-2012	2013-2014
Akgün et al. [1]		x								Teacher				x
Aydın [2]		x								Teacher	x			
Bal, Doğanay [3]	x									Undergraduate				x
Beyazıt et al. [4]			x							Teacher			x	
Çiltaş [5]				x						Undergraduate			x	
Çiltaş [6]					x					Undergraduate			x	
Dede, Güzel [7]			x							Teacher				x
Dede, Güzel [8]									x	Teacher				x
Dede, Yılmaz [9]			x							Undergraduate				x
Dişbudak [10]				x						Primary				x
Doruk [11]			x							Primary			x	
Doruk [12]			x							Primary			x	
Doruk [13]				x						Primary		x		
Durmuş [14]						X				Undergraduate			x	
Dündar et al. [15]								x		Theoretical			x	
Eraslan [16]									x	Undergraduate			x	
Eraslan [17]			x							Undergraduate			x	
Erbaş et al. [18]								x		Theoretical				x
Güder [19]									x	Teacher				x
Güzel, Uğurel [20]			x							Undergradute		x		
Hıdıroğlu, Güzel [21]							x			Undergraduate				x
Hıdıroğlu, Güzel [22]								x		Theoretical				x
Kaf [23]					x					Primary	x			
Kal [24]				x						Primary				x
Karalı [25]			x							Undergraduate				x
Kertil [26]			x							Undergraduate	x			
Keskin [27]			x							Undergraduate	x			
Olkun et al. [28]					x					Primary		x		
Özaltun et al. [29]			x							Undergraduate				x
Özdemir, Üzel [30]									x	Undergraduate		x		
Sağırlı [31]				x						High School		x		
Sandalcı [32]				x						Primary				x
Tuna et al. [33]						X				Undergraduate				x
Türker et al. [34]									x	Undergraduate		x		
Ural, Ülper [35]				x						Undergraduate				x
Ünveren [36]				x						Undergraduate		x		
Zeytun [37]			x							Undergraduate				x

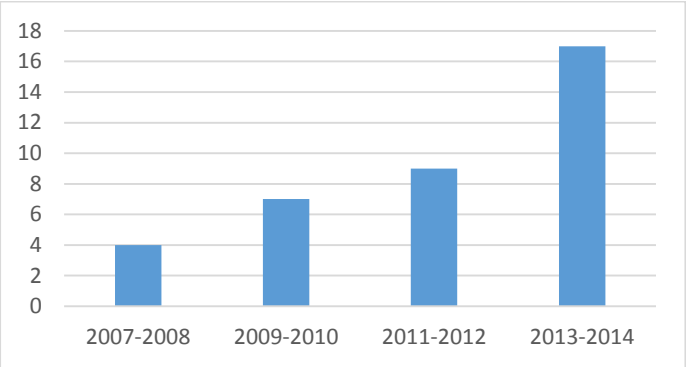
The validity and consistency of the study

The consistency of the themes were evaluated with respect to one another by considering the inner homogeneity and outer heterogeneity criteria for the validity of the study. In the methodology section, the procedures followed during the data gathering and analysis were explained in detail and the findings were presented using interpretation. The relevant documents were recorded and hidden to be subject to confirmation. For the consistency of the study, the themes were constructed according to the theoretical structure and the researchers took care to explain the analysis procedures completely. Moreover, for the outer consistency, the detailed explanation regarding the relevant concepts and procedures were given to the researchers for similar studies to be conducted. The appropriateness of studies to the themes were reviewed by two researchers and the inter-coder reliability was found to be 96,7 %.

Findings

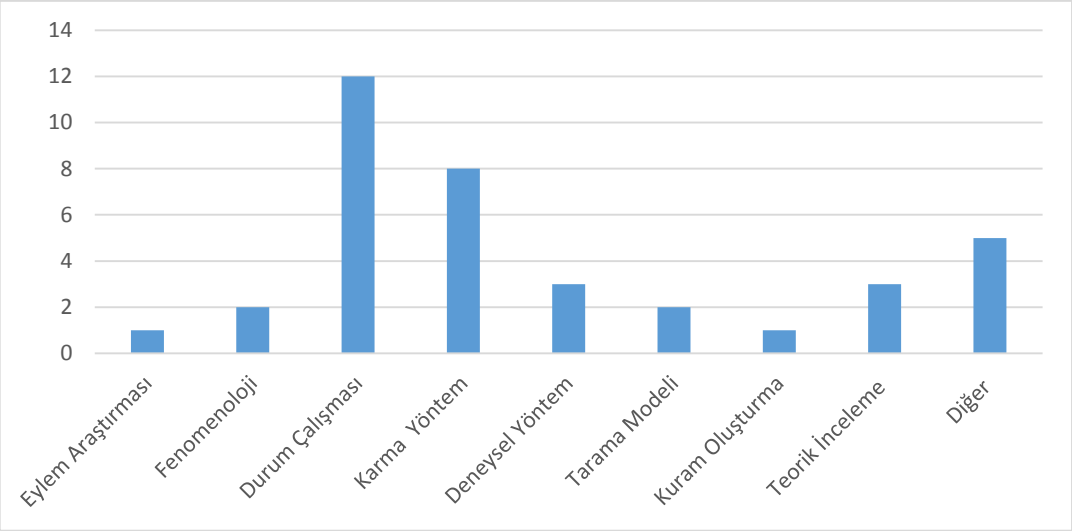
The findings of descriptive analysis:

In this section, the question, "How are Turkish mathematical modelling studies distributed according to their years, sampling and methodology?" is considered. According to the mathematical modelling researches considered in this study, the first research was conducted in 2007 in Turkey. The distribution of recent modelling studies by years is given in Graph 1.



Graph 1. Distribution of studies by years

The findings concerning the sampling groups of the studies displayed that 19 of 37 studies involved student teachers in their sampling groups. More than the half of the studies were conducted with undergraduate university students. Since this study includes nearly all of the mathematical modelling studies conducted in Turkey except the presentations at the congresses, it can be said that few studies (9) have been conducted whose participants are elementary and high school students. Only one of these studies was conducted with high school students. Excluding theoretical studies (3), the participants of remaining studies (6) were teachers. When the studies are compared in terms of their research methodologies, it will be seen that most of them are qualitative study. Nearly half of these qualitative studies are case studies. Kertil [26] emphasized that providing deep analysis of a special case and the opportunity of using qualitative and quantitative methods together are the advantages of case study. On the other hand, in mixed-method research the major approach is quantitative. The embedded design was usually preferred in which the experimental design was supplemented with qualitative data obtained by interviewing participants. Also, the researchers met with studies (3) conducted using only experimental design. It was seen that other studies used various qualitative research methodologies such as phenomenology (3) or action research (1). Moreover, theoretical studies (3) that aim to explain the epistemology of the mathematical modelling domain have become prevalent in recent years.



Graph 2. Distribution of studies by methodologies

Generally, the common point of the case studies is the deep analysis of the cognitive processes of participants during mathematical modelling processes. In these studies, the researchers determined some knowledge and abilities ([11], [12], [26], [27]), the representations used by participants [29], and the competencies [9], difficulties and obstacles encountered ([17], [26], [34] within the modelling processes. A noteworthy result is that relevant studies generally stated that students have trouble with constructing mathematical models for real-word problems or adapting models to real-life situations. These studies ([4], [25]) also focus on individuals' thoughts about model, modelling and mathematical modelling. However, there are other studies that focus on mathematical modelling whose methodology is different from case study. They identified opinions that emerged during or at the end of the mathematical modelling processes. These studies were conducted with teachers ([1], [4], [19]) pre-service teachers ([16], [30], [34], [37], [25]) and high school students [31].

When the opinions of the participants obtained by qualitative techniques are analyzed, they can be summarized roughly as follows: From a positive perspective,, mathematical modelling leads to a better understanding of lessons, permanent learning, a visualization of mathematical concepts and to increasing attention and motivation ([1], [19]); when regarded negatively, mathematical modelling process takes time and it can be difficult to construct and use mathematical models in the class. Generally, it is emphasized that all curricula should involve mathematical modelling ([1], [19], [34]). A common view is that mathematical modelling can mostly be used with fractions, counters, algebraic identities and algebra tiles ([1], [4], [19]).

The results (Table 4) of the studies that use model-eliciting activities stated that modelling not only can provide some affective benefits (increasing concern, taking pleasure) but can improve students' capacities for finding solutions for real-world problems, high order thinking, viewing subject matter from different perspectives, describing themselves, creating new ideas, developing empathy and facilitating socialization ([16], [30], [34], [25]). These studies also mentioned the obstacles and anxieties emerged during model-eliciting activities; uncertainty, higher order thinking requirement s that changes according to the perspectives, excessive pace during the application stages of the lessons, and insufficient time ([16], [30], [37], [25]). From a pedagogical perspective, the results stated that modelling should be realized by provision of a collaborative discussion environment, the teacher should also possess some specific abilities; he should be a leader and supporter, he should be able to dominate the class and he should have active and effective communication skills ([31], [16], [30]).

Table 4. Opinions analyzed using qualitative methods

Positive Opinions About Mathematical Modeling	A better understanding of lessons and permanent learning, [1] İncreasing attention and motivation [1], [19]
Negative Opinions About Mathematical Modeling	Mathematical modelling process takes time [1] It can be difficult to construct and use mathematical models in the class [1]
Opinious Towards Curriculums	All of the curricula should involve mathematical modelling [1], [34], [19]
Topics most used mathematical modeling	Fractions, counters, algebraic identities and algebra tiles [1], [4], [19]
Benefits of Model Eliciting Activities	Increasing concern, taking pleasure [30] Finding solutions for real-world problems [30], [34] Describing themselves, experiencing empathy and facilitating socialization[16] Creating a new idea[16],[25]
Obstacles Emerged During Model-Eliciting Activities	Excessively fast pace during the applications [30] Insufficient time [37] Uncertainty [16], [25]
Teacher's Characteristics During Implementation Model-Eliciting Activities	A leader and supporter, Dominate the class and, Active and effective communication skills [31]

The findings from the meta synthesis:

In this section, the questions, "For which goals and in which ways mathematical modelling is used in modelling studies in Turkey?" and "Which modelling perspectives were commonly preferred in the studies?" are considered.

The "goal" and "usage" themes:

The studies were analyzed according to their goals within the framework of the themes; "pedagogical", "affective", "process" and "theoretical" that were explained in the methodology part. The main purpose of this detailed analysis is to differentiate the goals expected from modelling and the modelling perspectives in the studies. For example there is a "theoretical" study that aims to explain theories related to modelling while it handles modelling within the cognitive modelling perspective. Table 5 displays the distribution of studies according to the theme that identifies the goal of mathematical modelling.

Table 5. Distribution of studies by the goal of modelling

THEME	SUB-THEME	SAMPLE STUDIES	FREQUENCES (PERCENT)
GOAL	Pedagogical	(Çiltaş,2011)	20 (% 49)
	Affective	(Ünveren,2010)	9 (% 22)
	Process	(Hıdıroğlu and Güzel, 2013)	9 (% 22)
	Theoretical	(Erbaş et.al., 2014)	3 (% 7)

Table 5 shows that nearly half of the studies have pedagogical goals that include the better understanding of mathematical concepts and improving students' knowledge, abilities and academic performance. Generally, in these studies, modelling activities and modelling problems were employed during the teaching processes and making sense of mathematical concepts was emphasized. It was seen in these studies that, mathematical modelling exerts a positive effect on teaching processes. The result is similar for the studies that have affective goals which determine the impact of modelling on

students' attitudes. Table 5 also shows that the same amount of studies have been conducted within the themes of "affective" and "process". Although there are many studies in the literature that aim to understand the modelling process, it is not possible to define a common shared description for the modelling process which identifies the transition process from the real world to mathematics or vise versa (Blum & Ferri, 2009). As a result, it is thought that studies that aim to reach an understanding regarding the modelling process will continue in the future. There are few studies (4) that can be placed within more than one theme, for example there is a study that has both "pedagogical" and "affective" goals [3]. The researchers thought that this limited number may show the difficulty of multi-goal modelling studies.

Table 6 displays the distribution of studies according to the "usage" theme. This theme corresponds with which components of teaching processes mathematical modelling is used.

Table 6. Distribution of Studies by the "Usage" Theme

THEME	SUB-THEME	SAMPLE STUDIES	FREQUENCES (PERCENT)
USAGE	Activity	(Doruk, 2012)	23 (% 71)
	Problem	(Kertil, 2008)	8 (% 24)
	Technology	(Aydın, 2008)	2 (% 6)

According to Table 6, most of the modelling studies were conducted with activities.It is thought that the effect of commonly used teaching approaches in recent years that are based on socio-cultural and constructivist theories like "modelling and modelling perspective" and activity-based studies emphasized in the new Turkish mathematic programs can be the cause of this result. Also, it can be thought that authentic and purposeful real life situations actually can be introduced to students more effectively by model-eliciting activities that are in fact problem situations constructed with particular design principles. In conclusion, modelling studies have become relatively widespread thought the employment activities in Turkey. On the other hand, in nearly one-quarter of the studies, modelling was conducted by using problems and few studies (2) were conducted in a digital environment. Since there are many projects for using technology to enhance education (Akgün et al., 2011), not assigning a priority to through modelling studies utilizing mathematic software may be considered as a deficiency of math education studies in Turkey.

"General Use" and "Modelling Perspective" Themes:

In this section modelling studies in Turkey will be analyzed according to the approaches in the literature mentioned above. Table 7 displays the distribution of studies according to the "general use" theme that defines the purpose of the use of mathematical modelling in the studies.

Table 7. Distribution of studies by the "general use" theme

THEME	SUB-THEME	SAMPLE STUDIES	FREQUENCES (PERCENT)
GENERAL USE	Purpose	(Özer Keskin, 2008)	12 (% 32)
	Vehicle	(Sandalcı,2013)	25 (% 68)

Overall, there are more studies that consider mathematical modelling as a vehicle used for teaching mathematics and the studies that consider modelling as a purpose make up half of them. The researchers think that since teaching modelling capabilities and strategies may increase the usage of mathematical modelling in education, there is more need for studies that aim to develop mathematical modelling capabilities and teach modelling.

The studies were also analyzed according to the modelling perspectives stated by Kaiser and Sriraman's (2006). Although it is not possible to differentiate these perspectives precisely; the researchers, who independently coded the studies according to these perspectives , did not come to an agreement on only one study and this disagreement may be the result of characteristic of educational

perspective according to the researchers because this perspective can be thought as an integration of realistic and contextual perspectives (Erbaş et al., 2014). Through this analysis, the researchers aimed to determine the course of the mathematical modelling studies in Turkey according to the literature. Table 8 displays the distribution of studies according to the "modelling perspective" theme.

Table 8. Distribution of studies by the "modelling perspective" theme

THEME	SUB-THEME	SAMPLE STUDIES	FREQUENCES (PERCENT)
MODELLING PERSPECTIVE	Realistic	(Doruk, 2010)	6 (% 15)
	Contextual	(Dişbudak, 2014)	11 (% 28)
	Educational	(Olkun et.al., 2009)	13 (% 33)
	Cognitive	(Tekin Dede and Yılmaz, 2013)	7 (% 20)
	Epistemological	(Dündar et. al., 2012)	2 (% 5)

According to Table 8, educational and contextual perspectives were encountered most frequently in mathematical modelling studies. Thus, in nearly two-third of the studies, mathematical modelling was realized in the context of the general understanding of a mathematical concept ([10],[36],[1],[23]), in developing teaching processes ([28], [4], [11], [12]) or real life situations for making sense of ([10], [8], [36], [20]). these Most of the studies (15) in these two sub-themes benefit from the model-eliciting activities in the perspective of models and modeling perspective. The most important problem the researchers encountered was that there was not enough explanation of the application procedure of model-eliciting activities in most of these studies.

One-fifth of the studies focused on modelling process within the cognitive perspective. Generally, the difficulties that students encountered during the modelling process were discussed in these studies which researched the mental processes that occurred in the modelling process. Apart from these studies, there are some studies that investigated how students can benefit from modelling to cope with real-life problems and how much modelling studies affect the students ability of using mathematics in daily life. These studies were considered in the "realistic" modelling perspective sub-theme. It is thought that the number of studies in this perspective would be much larger if the mathematical modelling studies in other areas such as engineering and application mathematics were considered. Finally, the researchers handled the studies investigated the relevant theories about mathematical modelling in the epistemological perspective. They could find only two studies that can be considered in this sub-theme ([15], [18]).

Conclusion, Discussion and Propositions

When the mathematical modelling studies carried out in Turkey are analyzed, it can be seen that a sufficient level content and diversity have not been obtained despite a rapidly growing number of studies. It was found that a great majority of mathematical modelling studies have been conducted, most of which are qualitative studies are case studies or mixed method studies. Apart from these, very few methods such as phenomenology and grounded theory were used. There were also studies which were not carried out within a certain research model framework, but instead mostly as descriptive studies through the employment of qualitative research methods (5 studies). This case fits with the findings obtained by Karadağ (2010) in his study. Karadağ ,in his study in which he analyzed the doctoral theses carried out in Turkey, concluded that some studies were carried out without designing a model or without the necessity to explain the design (of the model) in one of the parts of the study. However, according to Karadağ it is compulsory to follow a research model in the studies in terms of guiding the study (meaningfully) (Türkdoğan, 2003 cited in Karadağ, 2010).

In order to develop the processes and skills for using mathematics in real life meaningfully, it is asserted that mathematical modelling studies should be carried out starting from the elementary years of education (Jones, Langrall, Thornton, &Nisbet, 2002 cited in English and Watters; 2004). This assertion invites us to carry out similar studies at each teaching levels. However it is seen that mathematical modelling studies are mostly carried out with prospective teachers. This situation can be seen as a sign that the researchers are unable to benefit suficiently from schools that have facilities for the implementation of modeling with young students. The researchers may prefer studying with prospective teachers in the universities instead of doing a study in the schools because of the bureaucracy involved. On the other hand, it can be understood that both researchers and teachers may struggle with the carrying out a well-qualified mathematical modelling studies with young students. As a matter of fact, it can be said that studies with young students require more pedagogical content knowledge.

Kaiser and Sriraman's (2006) epistemological perspective sub-theme considers the studies in which mathematical modelling is used for the comparison of mathematical concepts or the studies that provide theory development by using models constructed from a situation (Revuz, 1971). However, the researchers could not find this kind of study among the math education studies in Turkey. A similar situation is also valid for socio-critical modelling perspective which emphasizes the role of mathematical modelling in the society. The points raised, such as improving teaching processes, providing meaningful learning and reaching a better understanding for a subject are mostly discussed in mathematical modelling studies carried out in Turkey. Most of the studies were conducted within the framework of an educational and contextual modelling approach. In addition to this, mathematical modelling is used as an instrument in mathematical modelling studies carried out in Turkey and mainly pedagogical objectives are pursued. On the other hand, the fact that the studies carried out in schools are highly limited requires a review of the objectives of the studies. In other words, the studies which should be carried out in schools with different learner levels are being conducted with university students. According to this, it is thought that it is impossible to provide sufficient support for the mathematical modelling literature which is emphasized in middle and high school mathematics programs.

It is seen that mathematical modelling studies are carried out generally with the employment of activities. An activity is expressed as fulfilling a task together with a certain pedagogic approach (Özmantar et all., 2010). In this case, the important aspect to consider is how the activity is carried out and to what degree the teacher is interested in the activity. For this, together with the quality of the activity, the form of the activity is also becoming important. It is suggested in the studies conducted for the activities that how the implementation is conducted should be particularly emphasized. In particular, placing more emphasis on the design principles of modelling activities which are discussed

within the contextual approach of the modelling approaches and which is asserted by model and modelling perspective approach can prevent misunderstandings.

It was stated in a few experimental studies conducted in Turkey that teaching processes carried out with mathematical modelling usually enhance the academic achievement and the usage of mathematics in daily life. However, because of the limited number of these studies and insufficient details in these studies about how teaching was conducted with mathematical modelling, it is not possible to analyze the effect of mathematical modelling more systematically and in greater detail. Specifically, it is required to conduct studies that will investigate under which conditions and in which ways the teaching carried out with mathematical modelling may be more effective.

There were 10 studies that analyzed the cognitive processes of participants during mathematical modelling processes or how much the target sample completed the determined cognitive processes. These studies focused on the modelling process which was usually carried out according to the "cognitive" perspective and the "goal" theme. One of the obvious problems in these studies is the sample diversity in that they were generally conducted with teachers. Thus, in general, the modelling processes of undergraduate students were encountered in the studies. This reality decreases the effect of modelling studies in Turkey. It is thought that the policy maker should take account of cooperation problem between schools and universities.

The researchers did not encounter any study in the qualitative mathematical modelling studies which used only document study method. Mathematical modelling, that is identified as a general purpose of various mathematics programs, should be investigated in course books and in other teaching materials by document studies. Finally, the researchers think that it will be useful to benefit from mathematical modelling to enhance the contents of digital teaching materials in teaching environments that use digital materials.

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