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MODELS AND MODELLING IN SCIENCE EDUCATION IN TURKEY: A LITERATURE REVIEW

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Abstract. *This research examined articles about models and modelling in the context of science education in Turkey by using content analysis method. Two specific academic databases; one of which was Dergipark, a platform including the academic journals published in Turkey, and Scholar Google were examined in detail so that totally 71 articles on models and modelling in science education were identified. The "article analysis form" developed by the researchers considering into the relevant literature was used to examine these articles. The findings were presented in tables and charts to show the frequency and percentile values regarding the articles examined. As a result, it was found that the purpose of most of the articles is to examine the effect of model / modelling-based teaching method. Concerning the discipline related in the articles, physics was seen to be on the top of the list, more specifically astronomy subject. As another result, qualitative research method appeared to be the most commonly used research method in the articles at hand. Lastly, it was found out that the most frequently examined variable was the mental model of the participants, and the most preferred data collection instrument was conceptual understanding test.*

Keywords: *content analysis, literature review, modelling in science, models in science, science education*

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Introduction

One of the main aims of the science education is to enable students to learn the basic concepts related to natural phenomena around them. Students are not only expected to make simple definitions of science concepts, but also to be able to make correct associations between them and to use them when explaining daily life events and situations in the world. Students can directly encounter some examples of science concepts or processes in their daily lives. For example, the student can directly experience evaporation and condensation while drinking tea at breakfast. However, it is not possible to directly observe or experience some science concepts. During the teaching of these concepts, which are called abstract concepts, the educational tools such as models and modelling (e.g., simulations, analogies, maps, diagrams, graphs) are needed. The models and modelling will help students visualize these concepts in their minds and embody abstract concepts, phenomena, or processes for them. In this context, models and modelling are of great importance, especially in the process of learning or teaching science in which there are many abstract concepts or processes. Therefore, they are at the centre of science education. In the context of science education, model and modelling are considered both as a tool and a method. In addition, they are included in contemporary teaching-learning approaches such as problem-based learning, project-based learning, design-based learning, and STEM based teaching.

Models are actually much more than concrete teaching materials used in lessons to help students understand a concept or process more easily. A model is the representation of a real object, phenomenon or process called "target" (Gilbert, 2011). Similarly, Ingham and Gilbert (1991) defined the model as the simplified representation that highlights the typical features of a system. According to Hestenes (2006), a model is a simple representation of interrelated real or imaginary structures. Models are scientific and mental activities used to make it easier to understand phenomena that look complicated (Paton, 1996). They play a major role in developing, testing, and sharing of scientific knowledge. They are also considered to be both an important element necessary for doing science and one of the consequential outcomes of scientific research (Gilbert et al., 2000). As a related concept, modelling refers to a process of building semantic relations between a specific theory and phenomena/objects (Greca & Moreira, 2000). Models and modelling are accepted as an essential part of both science and science education (Devi et al., 1996; Güneş et al., 2004; Treagust et al., 2002).

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The literature seems to particularly focus on characteristics of a model rather than its definition. Van Driel and Verloop (1999) have listed the characteristics of scientific models as follows:

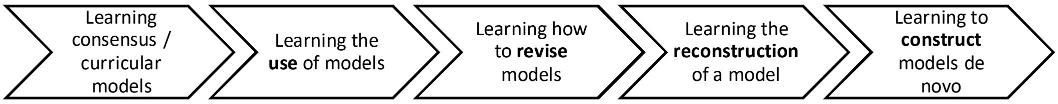
- A model is always associated with the target(s) it represents. The target can be a specific system, an object, a phenomenon, or a process.
- A model is a research tool used to obtain information about a target that cannot be observed or measured directly.
- A model is not in a direct interaction with the target it represents. Therefore, a photograph or a spectrum is not regarded to be a model.
- A model always differs from the target based on some distinctive details. In general, a model is simplified at the highest extent possible, excluding intentionally certain details of the target depending on the specific objectives of the research to be carried out.
- During creation of a model, the similarities and differences between the target and the model must be so clear that researchers can make predictions about what that model represents. This feature of the model is shaped by research questions in each research.
- A model comes to existence as a result of mutually influential processes, so it can be readjusted as more recent research studies are done about the target.

The review of the relevant literature shows that models are classified differently by different researchers. One of the most widely accepted classifications belongs to Harrison and Treagust (2000). Harrison and Treagust (2000) classified the models as analogical (scientific) models and personal (mental) models. Analogical models are further classified as scale models, pedagogical analogical models, symbolic (iconic) models, mathematical models, theoretical models, maps, diagrams and tables, concept process models, and simulations. On the other hand, mental models have personal and incomplete structure. A similar classification is also made by Ünal and Ergin (2006) and Ornek (2008).

Modelling can be described as the process of creating a model. It is the essence of scientific thought. Modelling is a central part of science literacy (Schwarz et al., 2009) and an essential tool for production, evaluation, and dissemination of scientific knowledge (Gilbert et al., 2000). It is a scientific process which may involve the processes of depicting the reality in detail, creating a model based on them, testing this model, and revising the model accordingly. Also, it is of great importance to bring modelling skills to students for science education. Justi and Gilbert (2002) in their research have described a procedure for teaching of modelling skills to students in science education. The phases of bringing students in modelling skill are shown in Figure 1.

Figure 1

The Phases for Acquiring Modelling Skill (Justi & Gilbert, 2002)



Using modelling process and models in teaching science is very crucial because they help students in understanding science. Modelling-based teaching is a teaching approach in which learning and teaching process is realised through modelling activities. This method also enables students to create and develop their own models so they can better understand the nature of science and related concepts by managing their own learning processes (Harrison & Treagust, 1998; Schwarz, 2009; Sins et al., 2009; Windschitl et al., 2008).

According to the Ministry of National Education of Turkey (MoNE, 2018), the goal of science education is to help students discover principles, concepts, and processes in the field of science, understand how scientific information evolves by directly participating in the scientific process, and lastly to improve their skills related to life, engineering, and design. Thus, the goal of science education can be summarised under two headings: to enable students understand basic science concepts and to enable them to acquire basic scientific behaviours or skills.

The ability of students to make sense of the events around them depends on their ability to understand basic science concepts and relate them to daily life. However, a considerable challenge faced in science teaching is students' failure to comprehend basic science concepts sufficiently. More often than not, previous research studies on science education have shown that students' levels of conceptual understanding of basic science topics (or concepts) are very low (Alkan et al., 2016; Coştu et al., 2007; Çalış, 2010; Frede, 2006; Kurnaz & Değermenci, 2012; Mann & Treagust, 2010). One notable reason for this could be the existence of abstract concepts and processes covered in science (Aksakal et al., 2015). In

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order to overcome this difficulty, model/modelling-based education, among others, can be used in teaching science. Model/modelling-based teaching of science helps students understand abstract concepts, allowing them to manage their learning processes by themselves (Chittleborough et al., 2005). Students have the opportunity to develop scientifically correct mental models thanks to the models and modelling activities used in science education (Chittleborough & Treagust, 2007). Model/modelling-based teaching increases students' conceptual understanding and success levels (Ergün & Sarıkaya, 2019; Schwarz & White, 2005), helps to eliminate their existing misconceptions (Ergün & Sarıkaya, 2014; Okumuş & Doymuş, 2018), and builds a positive attitude towards the course and learning (Türk & Kalkan, 2017).

Science courses also aim to provide students with some scientific behaviours and skills. Skill is defined as "the ability to apply knowledge, solve problems, and complete tasks" (Council of Higher Education of Turkey [CoHE], 2011). Possession of certain skills is inevitable for success in science. Modelling is one of those skills that has become quite popular in recent years. Modelling skill (ability) is a long-lasting and complex process that requires acquisition of a variety of other skills, takes fairly long and is a competence acquired gradually (Justi & Gilbert, 2002). Modelling skill is intertwined with many skills such as scientific literacy skill, scientific process skill, spatial skill, problem solving skill, and logical reasoning skill. Modelling skill both makes these skills mandatory but also contribute to development of them.

The importance of modelling skill has been noticed especially with the spread of innovative STEM/STEAM-based science teaching. Thus, many countries have modified their science curricula in order to provide students with the skill to do modelling in science. It is obvious that the countries doing well in science fields at international examinations such as PISA (Program for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) (Singapore, South Korea, Canada and Finland) have already appreciated this and placed the deserved weight on modelling skill as a part of their curricula (Ayvacı & Bebek, 2017). Likewise, the Ministry of National Education (MoNE) of Turkey has implemented innovation on science education curriculum acknowledging modelling skill to be one of the scientific process skills to be acquired by students and underlined its importance for science education (MoNE, 2018). Besides, The MoNE has started to establish the design-skill workshops to provide students with 21st century skills as well as modelling skill (MoNE, 2021). These workshops include STEM / STEAM activities. The education reforms carried out in Turkey had a positive impact on the results of PISA 2018 and TIMSS 2019 (MoNE, 2019, 2020).

Research Aim and Research Questions

When the literature on models and modelling in science education was examined, there was no research that examines the articles about models and modelling in science and aims to reveal tendencies in these research studies. The aim of the present research was to review articles on models and modelling in the context of science education in Turkey by using content analysis so as to elicit specific tendencies or trends followed by those articles. It is expected that the results will shed light on the overall status of research studies on models and modelling in science and thus pave the way for future researchers in this area. The research question of this research can be stated as following "What trends do articles on models and modelling in science education seem to follow?". In the context of the research question, the articles published on models and modelling in science education in Turkey were examined in terms of "year", "research aim", "topic or concept", "duration of implementation", "research method", "sample group", "sample size", "research variable" and "data collection instrument(s)".

Research Methodology

General Background

In this research, the document analysis method which is one of the qualitative research methods was used to review scientific articles on models and modelling in the field of science education. Document analysis can be used both as a research method and as a data collection method (Özkan, 2019). According to Yıldırım and Şimşek (2011), document analysis means analysis of materials containing information about phenomena and happenings under scrutiny. The summative content analysis method, which is a qualitative data analysis method, was used for the analysis of the data. The main purpose of content analysis is to gather similar data within the framework of certain concepts and themes and to interpret them in a way that the reader can understand (Yıldırım & Şimşek, 2011). The themes to be examined in the summative content analysis can be determined before or during the data analysis (Hsieh & Shannon, 2005). This research was conducted between May and July in 2020. The scope of the research was limited to empirical articles conducted from 2002-2019 on models and modelling in science education in Turkey.

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In the content analysis method, the information on the credentials of the examined research studies, their results or suggestions are presented to the audience in a more systematic manner by reviewing the literature on the subject under consideration, so that this type of research sheds light on new research studies to be conducted in the relevant field.

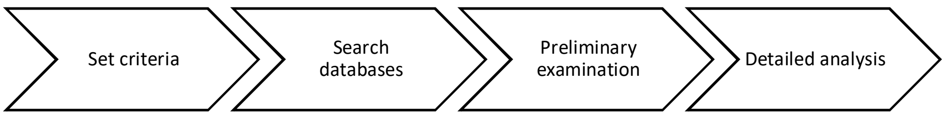
Sample

It was determined that 71 articles were conducted on models and modelling in science education in Turkey between the years of 2002 and 2019. All of these articles related to the purpose of the research have been included in the research. Therefore, the sample of the research consisted of 71 articles on models and modelling in science education from 2002 to 2019 in Turkey.

Instrument and Procedures

As seen in Figure 2, data collection and analysis of this research was completed in four stages. To start with, inclusion criteria were determined to select articles for review. Secondly, a search was done in the academic databases for access to articles that fell under the scope of this research. In the third step, articles complying with the criteria were picked up, downloaded, and subjected to preliminary review. Finally, those articles were analysed in detail by using summative content analysis.

Figure 2
The Steps for Data Collection and Analysis



As mentioned above, decision of inclusion or exclusion was made according to the inclusion criteria, which are given below:

- Articles must be published in a Turkish journal,
- Articles must be about science education,
- Articles must deal with models or modelling,
- Articles must be published in or prior to the year 2019,
- Articles must be available online.

On the other hand, articles were excluded if they were;

- Review research studies,
- Purely theoretical research studies,
- Scale development research studies,
- Document analysis research studies.

After deciding on suitable articles, a search was performed in online databases of Dergipark and Scholar Google and only those containing the term "Model" in the title were put on the list. Dergipark is a platform that offers electronic media and editorial process management service for academic journals published in Turkey (Dergipark, 2020). A preliminary review was conducted on the articles selected at this stage considering the main aim and inclusion criteria of this research. A total of 71 articles were determined and saved for detailed analysis. For analysing and coding the articles, a form called "Article Analysis Form (AAF)" was employed. During the preparation of the form, similar review articles (e.g., Albayrak & Çiltaş, 2017; Aztekin & Taşpınar-Şener, 2015; Küçüközer, 2016; O'Toole et al., 2018) performed in different fields by using descriptive analysis or content analysis were utilized and taken into consideration. The AAF was finalised in view of the aim of the current research. The final version of the AAF is attached as Appendix 1 to this article.

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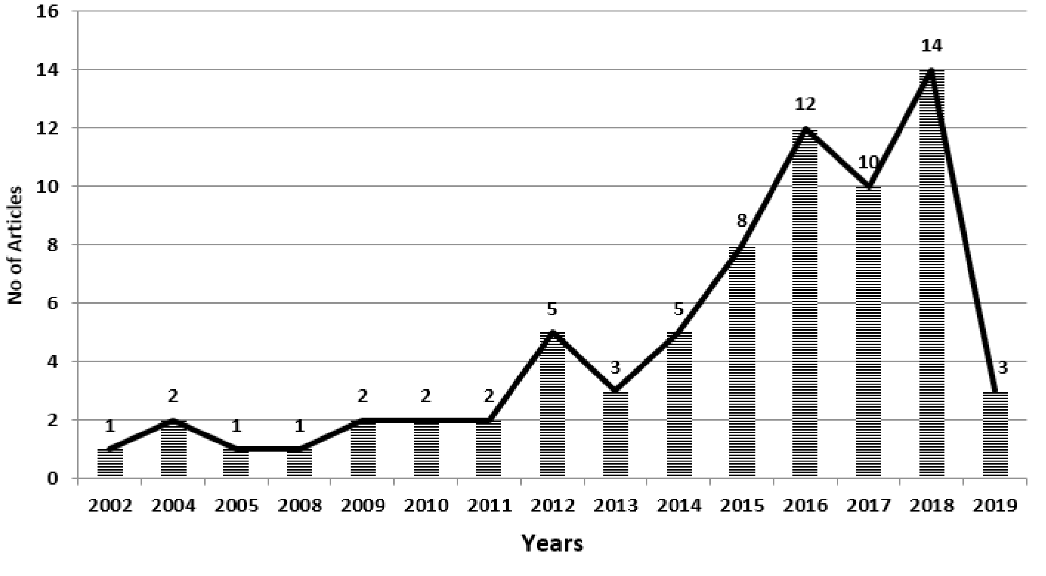
Data Analysis

The articles were coded by two independent coders using the AAF. For the reliability of the research, Cohen Kappa statistics between the coders were calculated. The resulting Cohen Kappa coefficient (>0.80) indicated an excellent level of compatibility between coders (Landis & Koch, 1977). The AAF was used to code the selected articles by the year of publication, research aim, selected focused science topic or concept, research method, sample group, sample size, research variable examined, data collection instrument, and duration of the implementation. The data obtained from the AAF were tabulated and displayed in charts along with figures of percentile and frequency.

Research Results

The results from the AAF were exhibited incorporating the percentile and frequencies in graphics and tables by using descriptive statistical methods. The distribution of the articles by year is shown in Figure 3.

Figure 3
Distribution of Articles by Year



As seen in Figure 3, there was an increase in the number of articles falling in the scope of this research, except during year 2019. It was found that the most articles on the topic of concern were published in 2018 (14 articles, 19.7%). Table 1 displays the distribution of the articles by research aim.

Table 1
Distribution of Articles by Research Aim

Aim	*f*	%
To determine the effects of model or modelling-based teaching	34	45.9
To examine mental models	24	32.4
To examine the views on the nature of models and modelling	10	13.5
To examine the views on model or modelling-based teaching	3	4.1
To examine the process of modelling	2	2.7
Other	1	1.4
Total	**74**	**100**

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It is understood from Table 1 that the majority of the articles reviewed here share the same research aim: to determine the effects of model or modelling-based teaching method (45.9%). The same articles were seen to determine the effectiveness of model/modelling-based teaching mostly by using experimental and control groups. Most of them were directed to increase the participants' understanding levels on selected concepts or their achievement level on the selected topic. The second most popular research aim was noted to be examining the participants' mental models regarding the selected science topic often by using open-ended questions and drawings as data collection instruments in a case/or descriptive research. The category "Other" covered one different research aim, which is comparison of scientific models in the science coursebooks with the mental models drawn by the students. The number of research aims was calculated bigger than the sum of the research studies reviewed since some of the articles had two or even three separate research aims. Table 2 shows the distribution of the articles in connection with the science topic or concept dealt.

Table 2
Distribution of Articles by Topic or Concept Dealt

Field	Topic	*f*	%	*f*	%
Biology				14	21.9
	Cell and Its Structure	4	6.3		
	Environment	2	3.1		
	Respiratory System	2	3.1		
	Plants	1	1.6		
	Urinary System	1	1.6		
	Circulatory System	1	1.6		
	Genetics	1	1.6		
	Microorganisms	1	1.6		
	Digestive System	1	1.6		
Physics				26	40.6
	Astronomy	14	21.9		
	Electricity	4	6.3		
	Work, Power, Energy	2	3.1		
	Sound	2	3.1		
	Light	1	1.6		
	Photoelectricity	1	1.6		
	Radioactivity	1	1.6		
	Optics	1	1.6		
Chemistry				24	37.5
	Matter and Heat	12	18.8		
	Atom and Its Structure	8	12.5		
	Chemical Reactions	3	4.7		
	Acid and Base	1	1.6		
Total				**64**	**100**

As Table 2 shows, physics was the most heavily examined field (40.6%). As for the subject of physics, astronomy, which encompasses the study of the Earth, the Sun, the Moon and space, was found to be the most frequently dealt topic (21.9%). On the contrary, the least research studies were carried out in the discipline of biology (21.9%). In some research studies covered here, more than one topic or concept was examined, while in some research studies, no topic was examined.

When the analysis of aims of the articles was further detailed (see Table 1), it was noticed that 34 of the 71 articles included some type of intervention (teaching practice). In those research studies, it was aimed at exploring the effectiveness of the teaching practices applied from various angles. The distribution of the teaching activities by duration is given in Table 3. However, some of them (n=6) did not report the duration of the teaching intervention.

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Table 3
Distribution of Articles by Duration of Implementation

Duration	*f*	%
1-3 weeks	10	29.4
4-6 weeks	15	44.1
7-9 weeks	1	2.9
10 weeks and above	2	5.9
Non-specified	6	17.7
Total	**34**	**100**

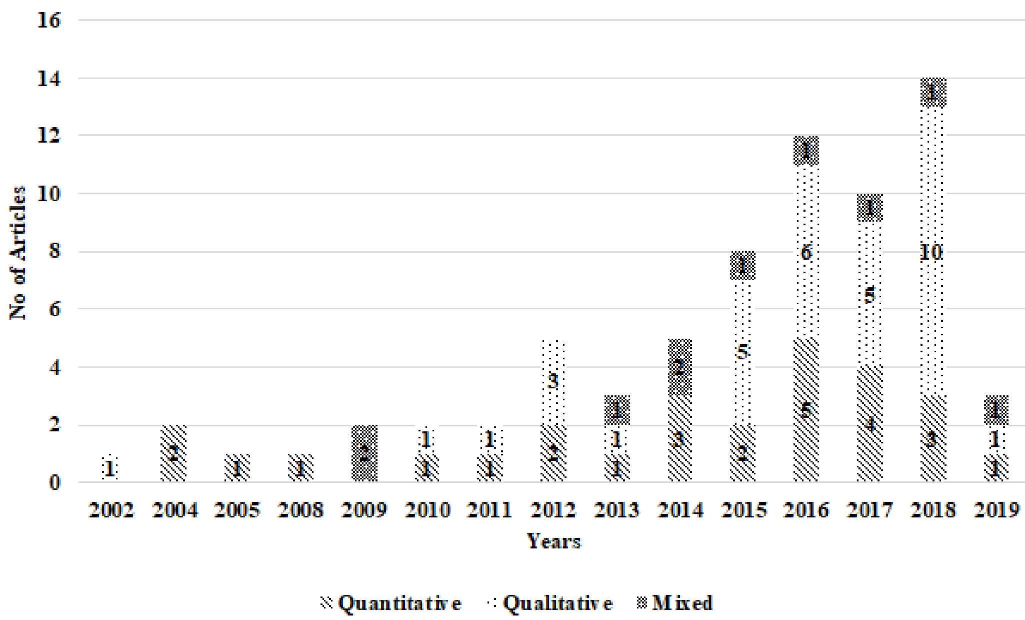
As can be seen in Table 3, the research studies with the practical period of 4 to 6 weeks had the biggest portion (44.1%) in the articles examined.

Apart from the foregoing, the distribution of the articles by used research method and distribution of the research method preference across years are displayed in Table 4 and Figure 4, respectively.

Table 4
Distribution of Articles by Research Method

Research Method	*f*	%
Qualitative	34	47.9
Quantitative	27	38.0
Mixed	10	14.1
Total	**71**	**100**

Figure 4
Distribution of research methods by year



As seen in Table 4 and Figure 4, the research methods of the articles were collected under three headings as quantitative method, qualitative method, and mixed method. During the analysis of the research methods, atten-

https://doi.org/10.33225/jbse/21.20.344

tion was paid to the type of data collected and data analysis methods as well as research methods reported in the article. In this respect, the examples with qualitative data (e.g., interview, citation) and qualitative data analysis methods only (e.g., content analysis, descriptive analysis) were named as qualitative; whereas they were coded as quantitative if quantitative data (e.g., data obtained from Likert scale or multiple-choice tests) and quantitative data analysis methods (e.g., t-test, ANOVA) were used only, and a blend of both of the abovementioned types of data led to the labelling as mixed type research method (Teo et al., 2014). It is understood from Table 4 that qualitative method was dominantly used in the articles (47.9%). In addition, Figure 4 shows that the number of qualitative research studies formed an incremental curve towards the end of the bar of years. The same is true for the number of quantitative research studies. However, the proportion of qualitative research studies tended to increase besides their number in the whole. As another sub-problem, the distribution of the articles here by their sample group is given in Table 5.

Table 5
Distribution of Articles by Sample Group

Sample	Sample Group	*f*	%	*f*	%
Postgraduate		1	0.8	1	0.8
Undergraduate				29	24.2
	Pre-service Biology Teachers	2	1.7		
	Pre-service Science Teachers	15	12.5		
	Pre-service Physics Teachers	3	2.5		
	Pre-service Chemistry Teachers	5	4.2		
	Pre-service Mathematics Teachers	3	2.5		
	Pre-service Pre-school Teachers	1	0.8		
High school (9-12)				6	5.0
	11th grade	1	0.8		
	10th grade	3	2.5		
	9th grade	1	0.8		
	Not specified	1	0.8		
Secondary school (5-8)				47	39.2
	8th grade	8	6.7		
	7th grade	20	16.7		
	6th grade	13	10.8		
	5th grade	6	5.0		
Primary school (1-4)				8	6.7
	4th grade	6	5.0		
	3rd grade	1	0.8		
	2nd grade	1	0.8		
Pre-school		4	3.3	4	3.3
Teacher/Lecturer				25	20.8
	Biology Teacher	4	3.3		
	Science Teacher	6	5.0		
	Physics Teacher	5	4.2		
	Chemistry Teacher	4	3.3		
	Mathematics Teacher	4	3.3		
	Lecturer	1	0.8		
	Primary School Teacher	1	0.8		
Total			100	120	100

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Table 5 demonstrates that the research studies reviewed here were chiefly carried out with secondary school students (39.2%), particularly 7th graders (16.7%). Of the samples at undergraduate level (24.2%), the most commonly examined sample group was found to be pre-service science teachers (12.5%). Some of the research studies consisted of heterogeneous sample groups, such as picking up of learners from various grade levels or both teachers and students at one time (Aydın et al., 2018; Görecek-Baybars & Çil, 2019; Şeren & Doğru, 2018). As for two-year associate programs or vocational high schools, none of the articles were found to target students attending those kinds of schools. Lastly, it was determined that the number of research studies implemented with learners from pre-school, primary and high school was quite low. The distribution of the articles by sample size is given in Table 6.

Table 6
Distribution of Articles by Sample Size

Sample Size	*f*	%
1-30 persons	13	18.3
31-60 persons	20	28.2
61-90 persons	12	16.9
91-120 persons	11	15.5
121 and above	15	21.1
Total	**71**	**100**

It can be seen in Table 6 that 28.2% of the articles reported results obtained from 31 to 60 participants. As another consideration in this research, the distribution of the articles by examined variables is shown in Table 7.

Table 7
Distribution of Articles by Variable Examined

Variable	*f*	%
Mental Model	26	27.7
Participants' Views	22	23.4
Level of Conceptual Understanding	19	20.2
Achievement Level	9	9.6
Misconceptions	5	5.3
Permanence of Learning	3	3.2
Attitude	3	3.2
Modelling Competence	2	2.1
Other	5	5.3
Total	**94**	**100**

Table 7 reveals that mental model (27.7%) and participants' views (23.4%) were the most commonly examined variables in all of the articles considered here. The articles in the category "Other" were seen to examine variables such as metacognitive awareness, creativity, spatial ability, conceptual change, and anxiety. Most of the research studies were conducted to examine more than one variable. Among categorical variables, it was seen that class level and gender were the most widespread factors, respectively. For instance, Bakaç and Kartal-Taşoğlu (2016) compared the effectiveness of the traditional teaching method and modelling-based teaching method in eliminating misconceptions of pre-service physics teachers about radioactivity subject according to gender. No significant difference was found between the participants' pre- and post-test results or scores obtained by the males and females. As another finding worth noting, it was seen that the selected variables did not include the 21st century's essential skills such as problem solving, critical thinking and reflective thinking. The distribution of the articles by data collection instruments is demonstrated in Table 8.

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Table 8
Distribution of Articles by Data Collection Instruments Employed

Data Collection Instrument	*f*	%
Conceptual Understanding Test	40	41.2
Questionnaire/Scale	22	22.7
Interview	20	20.6
Achievement Test	9	9.3
Document analysis rubric (Coursebook, students' activity documents, etc.)	3	3.1
Skill Test	2	2.1
Observation	1	1.0
Total	97	100.0

Table 8 points out that conceptual understanding tests became the most frequently used data collection instrument in all of the research studies (41.2%). Still, many research studies were realised with more than one single data collection instrument. The majority of the conceptual understanding tests comprised of open-ended items that require drawings. When it comes to those employing questionnaires/scales, it was seen that almost half of them used the questionnaire on the participants' views of models and modelling developed by Güneş et al. (2004), while the rest of them used their questionnaires/scales developed by themselves. As for the achievement tests, they were mostly in the form of multiple-choice tests. The skill tests included tests on creativity and spatial skills.

Discussion

In this research, an examination was carried out on Turkish articles discussing models and modelling in science education in order to expose the patterns of trends they follow. This section is dedicated to give an account of the findings and compare them with similar research studies.

First of all, it was seen that the first article about models and modelling in science education in Turkey was published in 2002, there was an increase in the number of such publications on an annual basis since then, the year 2019 being an exception, and the peak level was reached in 2018, the last of the years covered here. The reason for the tendency of rise could be the fact that the Ministry of National Education of Turkey adopted a revision on the science curriculum in 2013 and announced modelling to be a skill necessary for the field of science, which brought the topic to the attention of researchers. Albayrak and Çiltaş (2017), in his research, examined the obvious tendencies exhibited by research papers published in Turkey between 2004 and 2015 on mathematical modelling in the scope of mathematics education, and found out that the number of research studies on that topic was on the rise as years passed, not steadily though. It seems that the findings from Albayrak and Çiltaş (2017) lend support to the findings in the current research.

The analysis of the articles by aim of research demonstrated that the first place was occupied by the examination of the effectiveness of model/modelling-based teaching. In those research studies, the effect of that teaching style was often checked by using experimental and control groups. In the articles with this purpose, it is aimed to increase the levels of conceptual understanding or achievements of the participants by means of model or modelling based education. Albayrak and Çiltaş (2017) stated that the existing research studies on mathematical modelling generally aimed at teaching the participants mathematics by means of model/modelling-based teaching activities. It can thus be said that the results of this research are in congruence with those of Albayrak and Çiltaş (2017). Another prominent research aim adopted here was to bring out the participants' mental models in terms of various science topics or concepts by using data collection instruments such as open-ended questions that require drawings in the case or descriptive research studies examined.

Moreover, it was found out that the discipline which was examined most of all in the articles here was physics, astronomy standing out as the most frequently covered subject, which covers "the earth", "the sun", "the moon", and "the universe" concepts. In this regard, biology proved to be the least examined discipline/field, and "the cell and its structure" is most research study subject in the discipline of biology. The popularity of astronomy among the research studies in the scope could be due to the fact that astronomy subjects include macro phenomena or happenings and that most students have difficulty in understanding these events or concepts. Küçüközer (2016), in her far-reaching review of doctoral dissertations in science education, noted that physics was dealt with most respect to topics of force and movement, biology with

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respect to humans and the environment, and chemistry was examined in relation with the structure of matter. Doğru et al. (2012), in their analysis of postgraduate dissertations in science education, noted that the trendiest topics were "eco-system and ecology", "electricity", and "the structure of atom" in biology, physics, and chemistry education, respectively. The results of current research seem to be at variance with the findings obtained by Küçüközer (2016) and Doğru et al. (2012). It could be accounted for by the inclination towards topics posing specific difficulty of conceptual understanding when models and modelling come to attention. Besides this, it was observed in the research studies examined that the emphasis was placed on abstract topics (atom, heat, cell, etc.) and processes (the circulatory system, chemical reactions, etc.) that can be hardly visualised.

When analysed from the perspective of research method used, it was concluded that qualitative research method became the most preferential method. This finding is compatible with the previous review works on science education research (O'Toole et al., 2018) and mathematical model and modelling research studies (Albayrak & Çiltaş, 2017; Aztekin & Taşpınar-Şener, 2015). Nevertheless, it is not in compliance with the results of the review research focusing on chemistry education (Teo et al., 2014; Ulutaş et al., 2015), science education (Küçüközer, 2016) or instructional technologies (Göktaş et al., 2012; Hrastinski & Keller, 2007). As an obvious difference, the intensive preference for qualitative methods in current case can be said to be linked with the aims of the specific articles analysed here. In other words, the authors might have chosen a different research method each time considering its suitability for the specific facts of their research such as the discipline, aim, topic or year in question.

When the articles are analysed in terms of their samples, it becomes apparent that the most preferred sample group in the articles is secondary school students. More specifically, the 7th grade was noted as the most frequently preferred class level in secondary school. The second most common sample group was found to be pre-service science teachers. In a similar vein, Küçüközer (2016), in her review about doctoral dissertations in science education, indicated that the majority of the theses were conducted with secondary school students and especially with the 7th grade students. This leads to full congruence with current findings. On the other hand, there are some reports from review works on chemistry education (Teo et al., 2014; Ulutaş et al., 2015), mathematical models and modelling (Albayrak & Çiltaş, 2017; Aztekin & Taşpınar-Şener, 2015), physics education (Kaltakçı-Gürel et al., 2017; Önder et al., 2013) and biology education (Gül & Sözbilir, 2015) that the majority of those research studies were conducted on students at undergraduate level. It shows partial congruence with the current research as the latter noted that undergraduate students represented the second most common group of participants after secondary schoolers. As for sample size, the research studies examined here were prevalently implemented with 31 to 60 participants. It is in consensus with findings from other review research studies including physics education (Kaltakçı-Gürel et al., 2017; Önder et al., 2013), chemistry education (Sözbilir et al., 2013), biology education (Gül & Sözbilir, 2015) and instructional technologies (Göktaş et al., 2012). The sample group and sample size can vary depending on the aim, method, and other crucial aspects of each research, yet undergraduate students may have been preferred basically for convenience.

As another angle of current research, we found that the most widely examined variable was the mental models of the participants. In contrast, achievement was reported as the most prevalent variable in reviews of research studies in science education (Deniş-Çeliker & Uçar, 2015), physics education (Önder et al., 2013), chemistry education (Ulutaş et al., 2015) and biology education (Gül & Sözbilir, 2015). Bearing in mind that science includes abstract concepts or processes, it looks plausible to examine mental models more often than other variables in research studies on models and modelling in the field of science. Moreover, what matters most for the level of understanding and achievement of students on a particular topic is whether they possess scientifically correct mental models for the concepts or phenomena on that topic. It can thus be argued that it is a prerequisite to identify students' existing mental models for effective concept teaching. On the grounds of these two reasons, one would smoothly anticipate mental models as the most researched variable. However, it is a regrettable fact that no research studies were found to deal with the relationship between modelling skill and the vital skills for the 21st century, which had caused the curriculum to be revised and updated, such as problem solving, critical thinking, communication, information management and collaboration skills (Ananiadou & Claro, 2009; Binkley et al., 2012; Voogt & Roblin, 2012). It deserves consideration as employing modelling skill in science classes could possibly improve critical thinking, abstraction, and problem-solving skills. As another remarkable point, most of the research studies analysed here targeted cognitive domain, while there were only few examples looking over affective factors that could have a direct or indirect impact on learning such as attitude, motivation, anxiety, self-efficacy and self-confidence.

Considering the data collection instruments, it was seen that conceptual understanding tests were the most preferred tools. Most of such tests were comprised of open-ended questions which required the respondents to make drawings. Recalling that most research studies attempted to determine the mental models and the effectiveness of model or modelling-based education, it would not be surprising to come across that kind of questions as data collection instruments. The

https://doi.org/10.33225/jbse/21.20.344

most widely used data collection instruments appeared to be achievement tests in research studies concerning biology education (Gül & Sözbilir, 2015), science education (Küçüközer, 2016), and physics education (Kaltakçı-Gürel et al., 2017), while it was reported to be interviews by Albayrak and Çiltaş (2017) in his review on mathematical models and modelling. It is known that the goal of research examination of the effect of model/modelling-based education is to increase levels of conceptual understanding. For this reason, conceptual understanding tests were expectedly commonplace in the current research. It should be still noted that more than one data collection instrument was employed in most of the research studies examined here.

As the final sub-question of this research, it was found that the majority of the articles feature a teaching intervention applied to the participants. All of them can be seen to have intended to explore the effect of model/modelling-based teaching on a range of variables. They were not completed in the same period of time, and they mostly lasted for 4 to 6 weeks before completion of the experimental stage. Similarly, Kozikoğlu and Senemoğlu (2015), in their review on doctoral dissertations about education curricula and instruction, reached the conclusion that a vast number of such research studies completed their practical component within 4 to 8 weeks. In this respect, there can be seen conformity between the abovementioned research and the current one at a certain extent.

Conclusions and Implications

The aim of the research was to review articles on models and modelling in the context of science education in Turkey by using content analysis so as to elicit specific tendencies or trends followed by those articles. The articles were examined in terms of "year", "research aim", "topic or concept", "duration of implementation", "research method", "sample group", "sample size", "research variable" and "data collection instrument(s)". As a result, it was found that the purpose of most of the articles is to examine the effect of model / modelling-based teaching method. Concerning the discipline related in the articles, physics was seen to be on the top of the list, more specifically astronomy subject. As another result, qualitative research method appeared to be the most commonly used research method in the articles at hand. Lastly, it was found out that the most frequently examined variable was the mental models of the participants, and the most preferred data collection instrument was conceptual understanding test.

In view of the findings and discussion above, a number of recommendations were made for future researchers that are interested in models and modelling in science education.

- Even though most of the research studies in the field of science education have been carried out by using models designed by teachers, it is suggested to design learning environments to test their effectiveness in which students are supposed to create models and develop their modelling skills in future attempts.
- The relevant research studies have predominantly been planned to explore the effect of model/modelling-based teaching on students' achievement and mental models. In the future, unlike the inclination recorded so far, bigger emphasis could be placed onto affective traits of learners such as attitude, motivation, self-efficacy, and anxiety instead of cognitive variables.
- Again, future research studies can be directed towards portrayal of the relationship between model/modelling-based education and the skills needed in the 21st century such as problem solving, critical thinking, reflective thinking, communication, and collaboration.
- It is of great importance that young learners have more accurate mental models of basic concepts for them to be able to configure upper level concepts more accurately in their minds. To this end, concentration should be shifted onto learners in earlier years of education, which are pre-school and primary school levels.
- The MoNE of Turkey has made important innovations in the field of education. The MoNE has renewed all education curricula at primary, secondary and high school levels in the context of 21st century skills in 2018. In the new science curriculum, modelling skill was emphasized as an important skill that should be acquired by students. Also, the MoNE has started to establish the STEM-based design-skill workshops. These workshops offer valuable opportunities for students to develop their modelling skills. As a result of the education reforms, Turkey's PISA and TIMSS scores started to rise. The interest of researchers in Turkey on the model and modelling is increasing because of the emphasis on the importance of modelling skill in the renewed science curriculum, and the popularization of STEM-based design-skill workshops that include modelling activities. Research studies on modelling are invaluable and offer opportunities to increase the country's science literacy. With this research, the trends of articles on models and modelling in science education in Turkey were presented and the gaps in research studies were reported. A similar research can be carried out for a different country, and the results obtained can be compared in terms of countries' PISA and TIMSS scores.

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- In recent years, especially during the Covid-19 pandemic, content analysis studies have attracted the attention of many researchers and their number has increased day by day. Researchers working on a particular subject generally spend a lot of time to reach research studies on this subject in the relevant literature. At this point, content analysis studies provide important convenience. These types of research studies are of great importance not only for researchers working on this subject, but also for researchers who are just beginning to identify a research problem or subject to be examined. These researchers not only have the opportunity to see what kind of research studies have been conducted on a particular subject through, but also have the opportunity to see more clearly what gaps are in literature and which problems have not yet been examined. In addition, once researchers become aware of current research topics and trends in the literature, they may wish to do research on these topics. Therefore, the results of content analysis studies guide research studies on future. It can be said that this research is important because the articles on models and modelling in science education in Turkey were examined and evaluated in a comprehensive and holistic manner. The researchers who realize what kind of research studies are done in different countries can carry out the similar research studies in their own countries.

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Appendix 1

The Article analysis form (AAF)

Article Tag
Title
Author(s)
Year
Journal

Research Aim	Field/Topic
( ) To determine the effects of model or modelling-based teaching	( ) Biology / Topic:…….
( ) To examine mental models	( ) Physics / Topic:…….
( ) To examine the views on model or modelling-based teaching	( ) Chemistry / Topic:…….
( ) To examine the views on the nature of models and modelling	
( ) To examine process of modelling	
( ) *Other*	

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Research Method	Duration of Implementation
( ) Quantitative	( ) 1-3 weeks
( ) Qualitative	( ) 4-6 weeks
( ) Mixed	( ) 7-9 weeks
	( ) 10 weeks and above

Sample Group	Sample Size
( ) Postgraduate:….	( ) 1-30 persons
( ) Undergraduate Department/Program:….	( ) 31-60 persons
( ) High School/Grade:…..	( ) 61-90 persons
( ) Secondary School/Grade:……	( ) 91-120 persons
( ) Primary School/Grade:…….	( ) 121 persons and more
( ) Pre-school	
( ) Teacher / Lecturer	

Variable(s)	Data Collection Instrument
( ) Achievement Level	( ) Achievement Test
( ) Attitude	( ) Conceptual Understanding Test
( ) Level of Conceptual Understanding	( ) Document Analysis Rubric
( ) Mental Model	( ) Interview
( ) Misconceptions	( ) Questionnaire/Scale
( ) Modelling Competence	( ) Observation
( ) Participants' Views	( ) Skill Test
( ) Permanence of Learning	( ) *Other*
( ) *Other*	

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