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Developing a Scale to Determine the Knowledge of the Pre-service Teachers Related to Mathematical Modelling[*]

Mehmet BEKDEMİR[**], Yasemin SAĞLAM KAYA[***], Azita MANOUCHEHRI[****]

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ABSTRACT

This study aims to develop a scale to determine the pre-service teachers' knowledge about the mathematical modelling process. A survey method, among the quantitative research methods, was employed in the study. The data were collected from 380 pre-service mathematics teachers in the pilot study and 348 pre-service teachers in the main part of the study. The construct validity of the Mathematical Modelling Scale (MMS) that was developed, was verified with the exploratory and confirmatory factor analyses. As a result of the analyses, a scale with 13 items in 5-point Likert type related to the mathematical modelling process and three sub-dimensions as "Model (1-3 items)", "Modelling Process (4-9 items)" and "Curriculum (10-13 items)" was developed whose validity and reliability was verified. With the MMS, data can be collected from pre-service mathematics teachers as well as teachers. In addition, data collected with the MMS can be evaluated as a whole or the scores of the participants can be evaluated individually.

Keywords: Mathematical modelling, mathematical modelling scale, preservice mathematics teachers

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1. INTRODUCTION

The interest to teaching mathematical modelling in all grade levels has globally gained significant acceleration (Borromeo Ferri & Blum, 2009; CCSI, 2010; Czocher, 2018; Gravemeijer & Stephan, 2002; Greefrath & Vorhölter, 2016; Lingefjärd, 2006; OECD, 2017). The reason for the desire of developing mathematical modelling skills in all students originates from the benefits emerged by these sorts of mathematical applications (Czocher, 2018; Sokolowski, 2015). On the one hand, while modelling competencies take place at the center of effective functioning in real life and STEAM-related field; mathematical modeling enhances students' understanding of mathematics, fosters mathematical thinking, improves their problem-solving skills, and helps them develop a positive attitude toward mathematics (Blum & Borromeo Ferri, 2009; Gould, 2013).

Accordingly, mathematical modelling was included in the school curricula as a national skill/competence in several countries including Turkey, the USA and Germany (Blomhøj & Kjeldsen, 2007; Blum, 2011; Borromeo Ferri & Blum, 2009; CCSI 2010; MEB, 2013). But, recent researches about mathematical modelling suggest that transferring mathematical modelling added into curriculum into practice is not clear and easy as it is expected (Czocher, 2017, Doerr, 2007; Gould 2013; Zawojewski, 2013). Alhassan and Abosi (2014) put forward that the effective implementation of any new subject or competence, including mathematical modelling, depends largely on the knowledge and experience of the three factors: the subject, the effective pedagogical practices associated with teaching, and the value students place on the subject. In addition, as indicated in recent researches, there is evidence that many teachers don't have enough knowledge and experience about the implementation of mathematical modelling (Blum, Galbraith, Henn & Niss, 2007; Gould, 2013; Manouchehri, 2017). As a consequence of these researches, mathematical modelling was added in teacher training programs in Turkey in 2018 (YÖK, 2018). However, it is still not included in the teacher training curriculum in some countries (Borromeo Ferri & Blum, 2009; Erbaş, Kertil, Çetinkaya,

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[**] Prof. Dr., Erzincan Binali Yıldırım University, Faculty of Education, Department of Mathematics and Science Education, Division of Mathematics Education, Erzincan-TÜRKİYE. e-mail: mbekdemir@erzincan.edu.tr (ORCID: 0000-0003-1884-2938)

[***] Assoc. Prof. Dr., Hacettepe University, Faculty of Education, Department of Mathematics and Science Education, Division of Mathematics Education, Ankara-TÜRKİYE. e-mail: ysaglam@hacettepe.edu.tr (ORCID: 0000-0002-1615-0041)

[****] Prof. Dr., The Ohio State University, Collage of Education and Human Ecology, Department of Teaching and Learning, Columbus-USA. e-mail: manouchehri.1@osu.edu (ORCID: 0000-0002-2440-4929)

Çakiroglu, Alacaci & Bas, 2014). It also remains unclear how pedagogical courses on modeling, designed for teachers, may impact their understanding of the modeling process and its influence on teaching (Blum, Galbraith, Henn & Niss, 2007; Chapman 2007).

While some studies deal with how the modelling should be taught at schools (Blum & Leiss, 2006; Kaiser & Brand, 2015), others focus on the knowledge of the university students on modelling (Blomhoj & Kjeldsen 2007; Lingefjärd, 2007; Schwarz & Kaiser 2007). These researches, in addition to the modern teaching applications (Cai, Cirillo, Pelesko et al., 2014) such as mathematical modelling that can support the students' mathematical knowledge and competencies globally, suggest the necessity of better understanding of perceptions and competencies regarding modelling teaching in schools during teacher education (Erbaş et al., 2014; Gürel, 2018). This case is significant also in Turkey in parallel with the world as it can give hints about how the teacher training programs can be applied or improved. As a result, there is a need for a valid and reliable Mathematical Modelling Scale (MMS) to measure pre-service teachers' knowledge and competencies about the mathematical modelling process. The purpose of this study is to develop a reliable and valid scale to determine pre-service teachers' knowledge about the mathematical modelling process.

1.1. Literature Review

1.1.1. Mathematical model

The literature consistently defines mathematical modeling as a process and the mathematical model as its resulting product (Anhalt & Cortez, 2016). Reviewing the literature, it is seen that many definitions of the model and similarly the mathematical model have been made. For instance, the model is defined as an effort to create an analogy between a system you do not know and a system that is previously known or familiar with (Lehrer & Schauble, 2003). Lesh and Doerr (2003) describe a model as encompassing both the conceptual systems students hold and the external symbolic representations of these systems (For instance, ideas, representations and materials). In brief, a model can be defined as a tool that represents certain aspects of real life, rather than the entire situation (Greefrath & Vorhölter, 2016). A model may occur physical materials such as manipulatives, simulations or "designs" (NCTM, 2000). For this reason, models can be used to understand and interpret some aspects of real-life situations (Erbaş et al., 2014).

In the same way, a mathematical model can be defined as the representation of real-life situations through mathematical expressions (Greefrath & Vorhölter, 2016). Besides, Pollak (2003) refers to the mathematical model as describing mathematical representation of an idealized the real-life situation and then transforming it into a mathematical formulation. The main common feature of these various definitions is the emphasis on using a mathematical representation to understand a phenomenon or a real-world situation. Visual representations, equations such as concrete materials (for primary education), diagrams, two-way charts, graphs, flow charts, scaled map, architectural plans and a number line that can be used to define, explain and interpret the structural features or functional principles of a real-life phenomenon or situation and formulas are some examples of mathematical models (Anhalt & Cortez, 2016; Gould 2013; Lesh, Cramer et al., 2003; Lesh & Doerr, 2003). Additionally, it is noted that a mathematical model may encompass a series of representations, processes, and relationships to interpret real-life situations (Lehrer & Schauble, 2003, 2006). According to Lesh and Harel (2003), activities that bring out the model must emerge from life experiences that may be beneficial for students' mathematical thinking, so that students can produce symbolic representations of everyday situations.

1.1.2. Mathematical modelling

As the mathematical modelling literature was reviewed, it is noticed that there is a common sense in the literature that mathematical modelling is viewed as a cyclical process in which real-life situation or problems are translated into a mathematical language, solved within a symbolic system, and tested in the real-life context (Blum & Borromeo Ferri, 2009; Haines & Crouch, 2007; Lesh & Doerr, 2003). For instance, Pollak (2003) defined mathematical modelling as the process of creating, applying, revising, and validating. Blum (2011) define mathematical modelling as the cycle (Figure 1) in which a real life situation occurs and is interpreted.

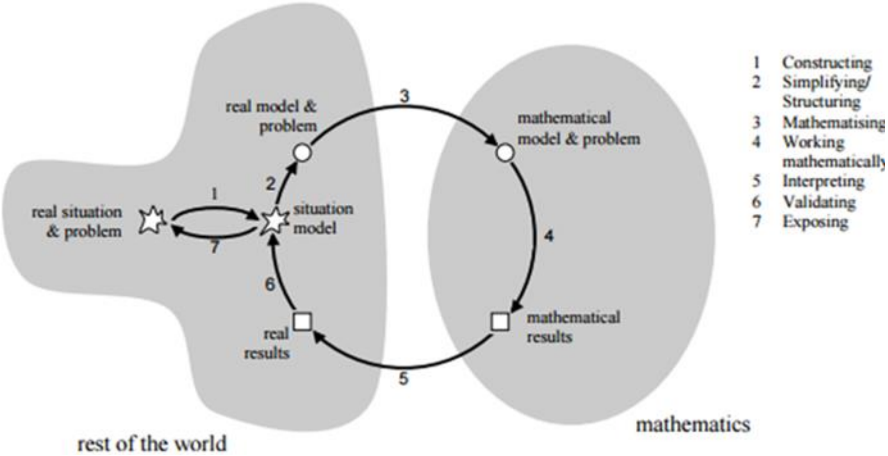

Figure 1. Modelling cycle (Blum, 2011, p.18).

In this cycle, the modeller's work towards understanding the situation leads to the generation of a state model. Simplification/configuration means defining, introducing, and specifying conditions and variables. With the help of mathematization, the modeller represents the mathematical model using mathematical tools and notations. Studying or analyzing mathematically produces mathematical results. Then, mathematical results are interpreted to get real results. These results are checked according to the situation model and verified. If the results are not acceptable or precise, a model revision, which leads to a repetition of a new cyclic process is formed. In the end, the modeller explains or shares the model to the stakeholders (Czocher, 2017).

According to the cycle model indicated in Figure 1, mathematical modelling process is defined in six basic steps. These are "Real Situation", "Situation Model", "Real Model", "Mathematical Model", "Mathematical Results" and "Real Results". In addition to the ability to define, mathematise, analyze, interpret and validate mathematical results related to real-life situations, relationships or predictions, checking the scope and features of the model, comparing models, working with models, changing or developing models in a cyclic way, evaluating models and their results, testing their validity and exposing the solutions are defined as Mathematical Modelling Competencies (Blum, 2002; Blum, 2011, p. 18; Niss, Blum & Galbraith, 2007).

Also, NCTM (1989) defined mathematical modelling as a cyclical process. This process; defining and simplifying a real-world problem situation, constructing a mathematical model, transforming the model and solving, interpreting the model, validating, and using. Therefore, mathematical modelling is also an iterative process due to the need for assumptions and other choices to develop a model (CCSI, 2010).

Considering the literature, although there are various definitions of mathematical modelling according to their objectives, there are some common features that characterize mathematical modelling. In short, these are non-linear and non-hierarchical, having a cyclical structure and iterative steps (Blum & Niss, 1991; Crouch & Haines, 2004).

1.1.3. Preservice mathematics teachers, mathematics teachers and mathematical modelling

In teaching modelling effectively, there is consensus in the literature that a new pedagogical approach should be improved and implemented in classrooms to help students develop modelling competencies (Czocher, 2017). Recent researches reveal that mathematics teachers have gaps in their knowledge and hold misconceptions about mathematical modelling and maintain these (Doerr, 2007). For example, Gould (2013) made research on secondary school mathematics teachers' understanding of mathematical modelling and modelling concepts and revealed that teachers had some lack of knowledge and misconceptions about these concepts and especially about the mathematical modelling perspective. Accordingly, some teachers do not know that the mathematical model is a mathematical representation of a real-life scenario, while others incorrectly believe that the mathematical model is manipulatives. Similarly, some teachers do not know that a mathematical model is a mathematical representation of a real-world situation rather than a representation with mathematical properties. In particular, she revealed that some teachers did not understand that the mathematical modeling process consistently involves making choices and assumptions, and that mathematical modeling situations must originate from real-world scenarios. It was also shown that some teachers did not embrace that the modelling process required iterative steps, checking and revising the models, and that the process was often cyclical. In addition, it has been put forth that some teachers do not accept that the modelling process can lead to the creation of various mathematical models and yield either approximate or exact answers.

In several studies, similar results were reached in terms of preservice teachers. According to these studies, preservice teachers had difficulties in expressing assumptions when dealing with mathematical modelling (Widjaja, 2013), in associating modelling with daily life (Tekin, Kula et al., 2011), in formulating a model (Turker, Sağlam & Umay, 2010), in interpreting and validating of results (Biccard & Wessels, 2011; Bukova-Güzel 2011; Gürel, 2018). In addition to this, some researchers suggested that the preservice teachers have widespread misconceptions about the nature of mathematical modelling and stated that a lesson or course on mathematical modelling may offer preservice teachers an opportunity to overcome these cognitive difficulties (Czocher, 2017; Doerr, 2007). Without doubt, undergraduate courses offer a way to deepen and improve the knowledge and experience needed for future mathematics teaching (Zazkis & Mamolo, 2011). While preservice teachers recognize modelling as a crucial skill to be developed in mathematics instruction, they believe that their limited experience with mathematical modelling during their training hinders their ability to organize their own pedagogical activities (Manouchehri, Yao & Saglam, 2018). So, it is necessary to investigate whether these lessons develop a sufficient mathematical modelling understanding that will help future students in preservice teachers. However, so as to provide effective guidance to future students in the mathematical modelling process, alternative assessment tools are needed to determine whether pre-service teachers have developed an adequate understanding of mathematical modelling.

2. METHODOLOGY

The survey method was employed in this study aiming to develop a scale. The survey method is generally applied to collect information about different variables such as individuals' behaviors, values, beliefs, wishes, opinions and their environment (Dilek & Sözbilir, 2021; Fraenkel, Wallen & Hyun, 2012; McMillan & Schumacher, 2012). Accordingly, the survey method was selected in this research as it was purposed to develop a scale with the pre-service teachers relevant to their mathematical modelling knowledge. The research was also found ethically appropriate with the decision of Erzincan Binali Yıldırım University Human Research Ethics Committee dated 18.12.2018 and numbered 11/28. 2020.

2.1. Participants

The participants in the study was chosen using convenience sampling. In addition, it is advised that the sample size in scale development studies should be between five and ten times of number of items when deciding on the sample size in scale development studies (Tavşancıl, 2014). In determining the total number of participants, this rule was taken into consideration. Two different participant groups were selected for the pilot study and main application.

The Participants of the Pilot Study: The participants in the pilot study comprised pre-service teachers enrolled in the Department of Elementary Mathematics Education (DEME) and the Primary School Teaching Department (PSTD) of a university in a medium-scale province, in terms of the population, of the Eastern Anatolia Region and the pre-service teachers at the Department of Secondary Mathematics Education (DSME) in a large scale province, in terms of the population in the Central Anatolia Region of Turkey. The distribution of these participants according to the department and grade level is presented in Table 1.

Table 1.
Distribution of the Pilot Study Participants According to Their Departments and Grade Level

	1st year	2nd year	3rd year	4th year	5th year	Total
PSTD	0	31	0	0	0	31
DEME	67	57	60	63	1	248
DSME	23	15	18	20	25	101
Total	90	103	78	83	26	380

According to Table 1, while the highest number of participants is in DEME, the lowest number of participants is in PSTD.

The Participants of the Main Application: The participants in the main application comprised pre-service teachers from the DEME and DSME in three different universities in a large-scale and a medium scale province in terms of the population in the Black Sea Region and the pre-service teachers studying at the DSME in a large-scale province in terms of population in the Eastern Anatolia Region of Turkey in the 2020-2021 academic year. All the participants voluntarily participated in the study. The distribution of the participants is presented in Table 2.

Table 2.
Distribution of the participants of the main application in terms of the department type and their Grade level

	1st year	2nd year	3rd year	4th year	Total
DEME	56	94	85	42	277
DSME	23	16	9	23	71
Total	79	110	94	65	348

According to Table 2, the highest number of participants is in DEME.

The pre-service teachers, who enrolled in pilot and main applications and studying at the DEME, have two ways to get information about the mathematical modelling process: The first is as a subject in the Methods of Teaching in their third year, and the second as an elective course on mathematical modelling in their fourth year if they select. The pre-service teachers, studying at the DSME, have the opportunity to get information about mathematical modelling as a subject within the Methods of Teaching course in a few hours. However, a different course is given to the pre-service high school mathematics teachers in modelling as an elective course.

2.2. Data Analysis

The content validity, whether the items in the MMS were relevant to the mathematical modelling was provided with the views of the three experts in mathematics education and the language validity with an expert in English and the other in the Turkish language. The construct validity of the MMS was tried to be provided with the exploratory and confirmatory factor analyses. Accordingly, the exploratory factor analysis was applied to determine the sub-dimensions of the items in the MMS with the SPSS 25.0 program. To explore the relationship between the factors that emerged as a result of the exploratory factor analysis and the relationship between the factors and the items, the confirmatory factor analysis was performed with the AMOS 22 program (Erkuş, 2016; Pallant, 2016; Tavşancıl, 2014). To determine the reliability of the MMS, the Cronbach Alpha internal consistency coefficient was calculated. For these analyses, whether the scores handled with the MMS had the outlier primarily or not and distributed normally was checked. As the result of the score analysis, it was observed that the data set had five different outliers. Since the number of outliers are very small (1%), all of these outliers were omitted from the data analysis. After the outliers were omitted, the skewness (.020, Sd=.132) and the kurtosis (-.669, Sd=.263) values are in the range between -1 and +1, it was seen that it appeared to meet the normality assumption in the analysis of normal distribution. On the other hand, while the histogram graph was close to the normal distribution, all points in the Q-Q graph were either on the diagonal line or very close to it. In addition, the boxplot was symmetrical in shape and contained no potential outliers. These graphical results demonstrated that the obtained scores met the normal distribution assumption. Accordingly, considering these scores, we decided that the exploratory and confirmatory factor analyses could be performed to determine the factors and items of the MMS and the Cronbach Alpha internal consistency coefficient could be calculated.

2.3. Development process of the MMS

The development process of the MMS is presented in Figure 2.

Figure 2. The steps of the MMS development process

The study was carried out by following the stages shown in Figure 2 in sequence.

2.3.1. Creating the scale items

In writing the items of the MMS, the items that Gould (2013) used in her study and relevant to the mathematical modelling process, then, the model in the literature, modelling processes and the features related to its inclusion in the curricula were taken into consideration by the researcher. There are two reasons for considering the items, developed by Gould (2013). The first is that the participants in this study are teachers. The second is that the items used in the study represent a holistic perspective about the mathematical model, the mathematical modelling, and why and how does the mathematical modelling take place in the curriculum. Accordingly, 20 items, in the study by Gould (2013), were translated into Turkish and arranged by considering the literature and the situations in Turkey. 18 of the 20 items in the formed draft MMS scale were referred to as positive; the rest two were negative. Finally, it was decided to scale each item in the draft MMS with a 5-point Likert type ((Totally Disagree (1) – Totally Agree (5)) for different analyses. Because the participants were asked to answer the items stated in the study by Gould (2013) as correct or incorrect and the reached results were able to be evaluated only as a percentage.

2.3.2. Content and language validity

For the language validity, firstly, 20 items were translated into Turkish by the researchers independently; then, a consensus was reached by discussing the words or meanings that could not be common among the translations. An expert in English, who also knows Turkish, and two academicians, who were expert in Turkish, examined this Turkish translation. According to their suggestions, necessary adjustments were made. For instance, while the word “strange” was used instead of the word “whimsical” by the researchers, the experts suggested using the word "weird" and the researchers used that word.

Henceforth, three experts in mathematics education were asked to examine whether the expressions of 20 items in the MMS were relevant to the mathematical modelling or not. The experts stated that these items were relevant to the mathematical modelling processes or their sub-dimensions (Model, Mathematical Modelling and Curriculum). Only, one of the experts claimed to use the concept of Mathematics Course Curriculum instead of the "standard" concept in some items and other experts supported this suggestion. Thus, instead of the "standard" concept, the concept "Mathematics Curriculum" was used in the MMS.

2.3.3. Pilot study

In the pilot study, 380 participants were asked to answer the draft MMS consisting of 20 items in 5-point Likert type, but not to affect each other or leave any blank items in this process. During this process, the researchers took notes about the questions asked by the participants. From the students’ questions, it was concluded that especially the two opposite items and an item, which were written as "strange (weird) or from unreal scenarios" were not adequately understood.

After the revision of these expressions by the field and language experts, some rearrangements were done on the items for the main application. To determine the obtained data, factors and items, the principal component analysis and vertical rotation to ensure maximum variability were analyzed using the varimax method. After the analysis, it was decided that the items were tended to gather under four factors in general. However, it was noticed that the overlap and factor load values of the three items were lower than .40. These three items were omitted from the scale. Thus, the MMS reached its final form consisting of 17 items graded in 5-point Likert type for the main application and all items were expressed positively.

3. FINDINGS

After the pilot study the MMS was transferred to the Google Forms by including the demographic information such as university, department, grade level and gender. 348 pre-service teachers who participated in the main application in the 2020-2021 academic year filled this MMS. According to the answers, the total score of each student was calculated. These scores were used for the analyses of the scale.

The construct validity was provided with the exploratory and confirmatory factor analyses. The Exploratory Factor Analysis is a statistical method that aims to reduce the number of variables by grouping a large number of variables and defining the main variables or factors. With the Exploratory Factor Analysis, first, the Kaiser-Meyer-Olkin (KMO) coefficient that provides a criterion for whether the data can be modelled with this factor structure, was calculated and found as .848. The literature suggests that the KMO coefficient value should be over .50 so that the dataset can be factored in (Tabachnick & Fidell, 2007). The coefficient of .848 supported that study data were suitable for modelling with this factor structure. In addition, the Bartlett Sphericity test was applied to determine whether the data demonstrated normal distribution or not and their suitability for the factor analysis. This test result significantly shows that the data were normally distributed and appropriate to the factor analysis (X^2 (136) = 1691.438, $p<.05$). Consequently, the results of the KMO coefficient and the Bartlett Sphericity test supported that the data had a structure appropriate to the factor analysis.

In the exploratory factor analysis, as the factorization method, the Principal Components Analysis and the varimax method were used. As a result of the Exploratory Factor Analysis, the criteria in determining the number of sub-factors were found as that the factor Eigenvalue greater than or equal to 1 in the literature, that the number of sub-factors up to the point where the vertical line becomes horizontal in the scree plot, that the total variance explained by the sub-factors is between 40% and 60% and that the contribution of each additional factor to the explanation of the total variance does not fall below 5% (Büyüköztürk, 2013).

As a result of the exploratory factor analysis performed with the data collected from the 348 pre-service teachers with the MMS, it was observed that four items in the scale were either overlapped or not grouped under any sub-factor. Therefore, four items were omitted from the scale and evaluation. For the rest 13 items, the exploratory factor analysis was redone. At the end of the analysis, the scree plot was formed in determining the number of sub-factors of the MMS at the end of the analysis and was presented in Figure 3.

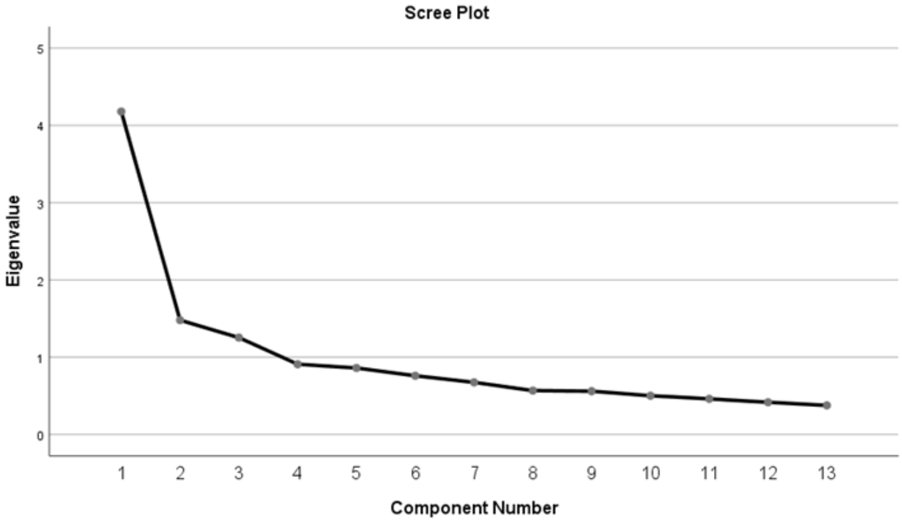

Figure 3. The Scree Plot graph of the MMS

As the scree plot in Figure 3 is analyzed, it is realized that the eigenvalue is greater than one and the MMS consists of three sub-factors according to where the vertical line becomes horizontal. In addition, as a result of the exploratory factor analysis, the eigenvalue of the sub-factors, the variance they explained and the percentage of total variance were calculated and presented in Table 3.

Table 3.
Eigenvalues, Variance and Total Variance Percentages of Factors

Factor	Eigenvalue	Percentage of variance	Percentage of total variance
1	4.180	32.152	32.152
2	1.479	11.380	43.532
3	1.254	9.644	53.176

According to Table 3, it is seen that the eigenvalue of each sub-factor is greater than 1, the contribution of each additional factor to the explanation of the total variance is over 5%, and these three factors explain 53.176 per cent of the total variance. As the percentage of total variance explained is between 40-60%, it is appropriate to the MMS.

Consequently, in the exploratory factor analysis, the rotated component matrix with the varimax method of vertical rotation in the exploratory factor analysis are presented in Table 4.

Table 4.
Sub-factor and Load Values as a Result of Rotated Components Matrix Analysis

Items	Factors		
	1	2	3
9.	.765		
8.	.710		
10.	.660		
11.	.633		
12.	.632		
13.	.490		
16.		.803	
14.		.766	
15.		.764	
17.		.614	
1.			.787
3.			.736
5.			.451

According to Table 4, three sub-factors, whose sub-factor load values change between .803 and .451 were determined. It is seen that the load in each item in a sub-factor in the MMS is above .400 and six items in Factor 1, four in Factor 2 and three in Factor 3. As the item expressions in the sub-factors were examined, it was decided to name Factor 1 as "Modelling Process", Factor 2 as "Teaching Program" and Factor 3 as "Model".

As a result of the exploratory factor analysis, the “Maximum Likelihood Method” was used to confirm whether the three items take place in the sub-factors of the “Model”, six items in the “Modelling Process” and four items in the “Teaching Program”. The model fit indexes as a result of the confirmatory factor analysis were explored and demonstrated in Table 5.

Table 5.
First-level Multi-factor Confirmatory Factor Analysis Fit Index Values

	x^2	df	p	x^2/df	GFI	AGFI	CFI	NFI	RMSEA
Fit indexes	157.284	62	.000	2.537	.934	.904	.910	.862	.067
Good fit values				≤ 3	≥ .90	≥ .90	≥ .90	≥ .90	≤ .08

According to Table 5, it was reached to the conclusion that there was a significant fit between the data and the model (x^2 (62) = 157.284, p=.000). In addition, as the other fit indexes were analyzed, it is seen that the x^2/df value is smaller than three, the GFI, AGFI and CFI values are greater than .90, the RMSEA value is smaller than .08 and the NFI value is smaller than .90 but very close to this value. These results support that the model has a good fit with the data. In addition, Table 6 demonstrates that the data on whether the indicators of the dimensions in the model and the connection paths are significant.

Table 6.
Significance Values of Connection Paths with Indicators of Dimensions in the Model

Item	Path	Factor	β_1	β_2	SH	t	P
M1	<---	Model	.272	.652	.214	3.045	p<.01
M3	<---	Model	.339	.603	.175	3.446	p<.001
M5	<---	Model	.640	1			
M8	<---	Modelling Process	.604	1			
M9	<---	Modelling Process	.636	1.197	.134	8.923	p<.001
M10	<---	Modelling Process	.533	1.104	.141	7.841	p<.001
M11	<---	Modelling Process	.652	1.051	.116	9.073	p<.001
M12	<---	Modelling Process	.648	1.014	.112	9.032	p<.001
M13	<---	Modelling Process	.587	.884	.105	8.432	p<.001
M14	<---	Curriculum	.736	1			
M15	<---	Curriculum	.759	1.087	.091	11.95	p<.001
M16	<---	Curriculum	.709	.956	.084	11.393	p<.001
M17	<---	Curriculum	.534	.936	.107	8.793	P=000

*β_1= Standardized path coefficient, **β_2= Non-standardized path coefficient

According to Table 6, all path coefficients of the items under the "Model", "Modelling Process" and "Teaching Program" factors of the MMS are statistically significant (p<.001). As the standardized path coefficients are investigated, it is realized that the item with the highest effect on the “Model” sub-factor is M5 (β_1= .640), the item with the highest effect on the “Modelling Process” sub-factor is M11 (β_1= .652) and the item with the highest effect on the “Curriculum” sub-factor is M15 (β_1= .759).
According to these results, the model according to the standardized parameter estimates is shown in Figure 4 and the model according to the non-standardized parameter estimates is shown in Figure 5.

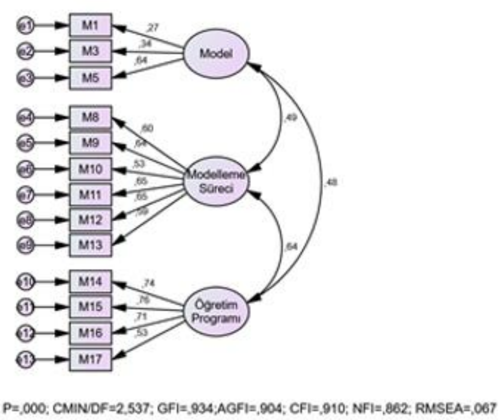

Figure 4. Standardized parameter model

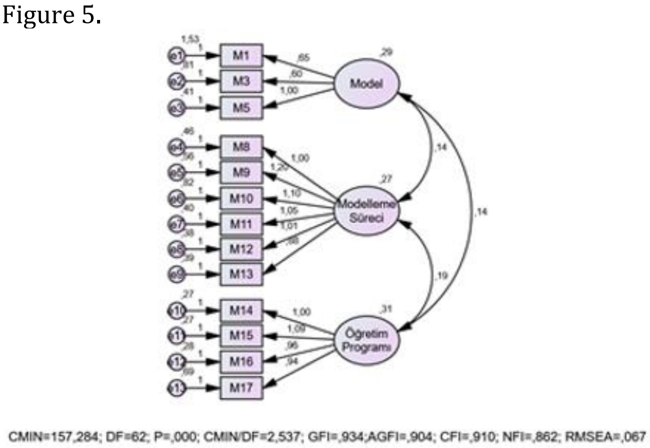

Figure 5. Non-Standardized parameter model

Related to the reliability analysis, firstly, the correlation matrix was calculated with the sub-factor and general total scores and presented in Table 7.

Table 7.
The Correlation Matrix Related to the MMS and General Total

	Model	Modelling Process	Curriculum	Total
Model	1			
Modelling Process	.167**	1		
Curriculum	.219**	.499**	1	
Total	.533**	.849**	877**	1

**p<.01

According to Table 7, there is a positive moderate and high level of a significant relationship between the sub-factor scores of the MMS and a positive weak and moderate significant relationship between the sub-factors (p<.01).

The Cronbach's alpha coefficient to determine the reliability related to the final scale emerged as a result of the factor analysis was calculated and presented in Table 8.

Table 8.
Reliability Statistics of the MMS and Its Dimensions

Factor	Number of Items	Cronbach Alpha Coefficient
Model	3	.504
Modelling Process	6	.775
Curriculum	4	.765
General	13	.783

According to Table 8, the Cronbach's alpha coefficient for the reliability of the scale was found as. 783. As this value is above .70 (Liu, 2003), the reliability of the MMS is sufficient.

In addition to these results, the MMS with 13 items in 5-point Likert type given in Annex 1 and which has three sub-factors called as "Model" (1-3 items), "Modelling Process" (4-9 items) and "Curriculum" (10-13 items) was created. The lowest score that can be taken from the MMS is 13; the highest score can be 65. A high score from the scale indicates a high level of mathematical modelling knowledge and a low score indicates a low level of this knowledge.

Consequently, the cluster analysis was applied to determine how the grouping would be done according to the scores from the MMS. The cluster analysis is used to divide scores from a scale into homogeneous subgroups. Clustering can be applied both with a single variable and depending on many variables (Cohen, Manion & Morrison, 2009). In cluster analysis in this study, the total scale score was taken into consideration as a single variable. In this regard, according to the total score from the MMS and the cluster analysis result, the groups and score ranges are as low (scores between 13-47), moderate (scores between 48-55) and high (scores between 56-65).

4. RESULTS, DISCUSSION AND RECOMMENDATIONS

This research aims to develop a scale to determine the knowledge of the pre-service mathematics teachers related to mathematical modelling. With this purpose, firstly, a scale consisting of 20 items in 5-point Likert type considering the mathematical modelling that Gould (2013) used in her study was created. Primarily, a pilot study was carried out with 380 pre-service mathematics teachers, and the number of items on the scale was reduced to 17. Later, the main application was conducted with 348 pre-service mathematics teachers. The validity and reliability analyses of the scale were performed with the data collected as a result of this application. With the analysis, the MMS consisting of 13 items with three factors was created. The MMS consists of three positive items with the expressions about the first sub-factor mathematical model called as "Model", six positive items among the expression about the second sub-factor about mathematical modelling process called as "mathematical modelling" and the third sub-factor called as the "curriculum", which contains four positive items about the relationship between the mathematical modelling and mathematics curriculum. The Cronbach's alpha internal consistency coefficient of MMS was found as .783.

As the literature was reviewed, it was decided to determine the knowledge or skills of students or teachers about the mathematical modelling process by examining the mathematical models put forward in a mathematical modelling situation/problem that was usually presented to them (Biccard & Wessels, 2011; Bukova-Güzel 2011; Gatabi & Abdolahpour, 2013; Gürel, 2018). In this way, it is both difficult and tiring to determine knowledge and skills about the mathematical modelling process. However, as the literature was taken into consideration, it is seen that there are restricted alternative methods or means to identify them. For instance, in the study by Gould (2013) related to the mathematical model and modelling acknowledging levels of the mathematics teachers, she wrote items relevant to the characteristics of the mathematical modelling process and asked teachers to give answers to the items as correct or incorrect. She expressed and evaluated the results she obtained only as a percentage. Although most of the items in the MMS, developed in this study, overlap with the items that Gould (2013) used in her study, the MMS has advantages in two sides. The first is that the factor structures put forward theoretically in the study of Gould (2013) were also provided statistically in the MMS. The second is that the scale items were converted into Likert type, which allowed different statistical analyses to be performed with the obtained data. On the other hand, as there is not any scale related to this topic as the literature in Turkey is reviewed, the MMS is even thought to be the beginning in this topic.

Consequently, a MMS, whose validity and reliability is provided, consisting of 13 items in 5-point Likert type with the sub-dimensions as "Model" (1-3 items), "Modelling Process" (4-9 items) and "Curriculum" (10-13 items) was created to determine the knowledge of the pre-service teachers in mathematical modelling process in this study. This MMS, developed with the participation of the pre-service mathematics teachers, can also be applied to measure the knowledge of mathematics teachers about the mathematical modelling process. In addition, as the total score from the MMS is classified as low (the scores 13-47), moderate (the scores 48-55) or high (the scores 56-65), the data from this scale can be analyzed as a whole or individually.

Research and Publication Ethics Statement

The research was found ethically appropriate with the decision of the Human Research Ethics Committee of Erzincan Binali Yıldırım University, with the decision numbered 11/28 and dated 18.12. 2020.

Contribution Rates of Authors to the Article

The first and second authors contributed 35% to this article and the third author contributed 30%.

Statement of Interest

The authors have no conflict of interest.

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APPENDIX

MATEMATİKSEL MODELLEME

Bu ölçek; matematiksel model, matematiksel modelleme süreci ve eğitimde matematiksel modelleme hakkındaki düşüncelerinizi belirlemek için hazırlanmıştır. Aşağıda verilen ifadeler ***"Hiç Katılmıyorum" (1)***'dan ***"Tamamen Katılıyorum" (5)'****a* doğru derecelendirilmiştir. Size en uygun olan seçeneği işaretleyiniz.

LÜTFEN SADECE BİR SEÇENEĞİ İŞARETLEYİNİZ.

(1) Hiç Katılmıyorum ⟷ ***(5) Tamamen Katılıyorum***

1.	Matematiksel model, ikinci dereceden bir denklem veya *x=v.t* yol-zaman gibi formüllerdir.	①	②	③	④	⑤
2.	Matematiksel model, sayı doğrusu veya grafik gibi görsellerdir.	①	②	③	④	⑤
3.	Matematiksel model, verilen bir durumun/problemin altında yatan nedenleri açıklar.	①	②	③	④	⑤
4.	Matematiksel modelleme sürecinde tekrarlanan adımlar, sürecin bir parçasıdır.	①	②	③	④	⑤
5.	Matematiksel modelleme süreci, tercihler yapmayı gerektirir.	①	②	③	④	⑤
6.	Matematiksel modelleme süreci, varsayımlarda bulunmayı gerektirir.	①	②	③	④	⑤
7.	Matematiksel modelleme süreci, gerçek duruma/probleme göre bir çözümün mantıklı olup olmadığının belirlenmesini gerektirir.	①	②	③	④	⑤
8.	Matematiksel modelleme süreci, düzeltmeler/düzenlemeler yapmayı gerektirir.	①	②	③	④	⑤
9.	Matematiksel modelleme durumu, çeşitli ve/veya farklı matematiksel modellerle sonuçlanır.	①	②	③	④	⑤
10.	Matematiksel modelleme, Matematik Dersi Öğretim Programında öğrencilerin günlük hayatlarında matematiğin kullanımını öğrenmeleri için yer almaktadır.	①	②	③	④	⑤
11.	Matematiksel modelleme, Matematik Dersi Öğretim Programında öğrencilerin öğrendikleri matematiği nasıl uygulayacaklarını öğrenmeleri için yer almaktadır.	①	②	③	④	⑤
12.	Matematiksel modelleme, Matematik Dersi Öğretim Programında öğrencilerin matematiksel olarak nasıl düşüneceklerini öğrenmeleri için yer almaktadır.	①	②	③	④	⑤
13.	Matematiksel modelleme, Matematik Dersi Öğretim Programında öğrencilerin matematiksel modelleri matematik dışındaki okul derslerinde nasıl kullanacaklarını öğrenmeleri için yer almaktadır.	①	②	③	④	⑤