BUEFAD | **2021**, Volume **10**, Issue **3,** 571-585

Bartın University Journal of Faculty of Education

dergipark.org.tr/buefad

DOI: 10.14686/buefad.871566

An Analysis of Pre-Service Mathematics Teachers' Behavior on Mathematical Modeling Cycle

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Research Article	Received: **06.02.2021**	Revised: **16.06.2021**	Accepted: **11.09.2021**

Abstract

The aim of the study is to determine the behavior on individual modeling cycle of pre-service teachers who participate in mathematical modeling learning environment and who do not. An action research method was employed in the study. The research participants consisted of 32 pre-service mathematics teachers, 17 of whom attended the learning environment while the rest did not. Two mathematical modeling tasks were used in the pre and post interview. In pre-interviews, pre-service teachers were interviewed individually, and the modelling routes of the pre-service teachers were closely monitored. At the end of the 11-week action plan, the post interview was made individually with the pre-service teachers. The recorded dialogues were analyzed during modeling cycles. It was determined that all pre-service teachers had a nonlinear cycle in the pre and post interviews. Pre-service teachers experienced in modeling repeated many steps back and forth. It was determined that they tried to revise the model when they reached a conclusion, so they had more complex modeling cycles. In addition, they mostly act in the world of mathematics. Pre-service teachers who are not experienced in modeling made a direct transition to real results without creating a mathematical model. It has been found that their areas of action are generally in the real world and they move less in the modeling cycle.

Keywords: Mathematical modeling, modelling cycle, modelling routes

Matematik Öğretmeni Adaylarının Matematiksel Modelleme Döngüsü Üzerindeki Davranışlarının İncelenmesi

Öz

Bu çalışmanın amacı, matematiksel modellemeyi öğrenme ortamına katılan ve katılmayan öğretmen adaylarının bireysel modelleme döngüleri üzerindeki davranışlarını belirlemektir. Çalışmada eylem araştırması yöntemi kullanılmıştır. Çalışma grubu, 17'si öğrenme ortamına katılan ve geri kalanı öğrenme ortamına katılmayan olmak üzere 32 matematik öğretmeni adayından oluşmaktadır. Ön ve son görüşmede iki adet modelleme durumu kullanılmıştır. Ön görüşmede öğretmen adayları ile bireysel olarak görüşme yapılmış ve öğretmen adaylarının modelleme rotaları yakından izlenmiştir. 11 haftalık eylem planı sonunda, son görüşmede yine öğretmen adaylarına bireysel olarak uygulanmıştır. Kaydedilen diyaloglar, modelleme döngüsü boyunca analiz edilmiştir. Tüm öğretmen adaylarının ön ve son görüşmede lineer olmayan modelleme döngüsüne sahip oldukları belirlenmiştir. Modellemeyi deneyimlemiş olan öğretmen adayları ileri geri birçok adımı tekrar etmişlerdir. Bir sonuca ulaştıklarında modeli revize etmeye çalıştıkları, bu yüzden de daha karmaşık modelleme döngülerine sahip oldukları belirlenmiştir. Ayrıca bu öğretmen adayları matematik dünyasında daha fazla hareket etmişlerdir. Modellemeyi deneyimlemeyen öğretmen adayları ise matematiksel model oluşturmadan gerçek sonuçlara doğrudan geçiş yapmışlardır. Hareket alanlarının genellikle gerçek dünyada olduğu ve modelleme döngüsünde daha az hareket ettikleri bulunmuştur.

Anahtar kelimeler: Matematiksel modelleme, modelleme döngüsü, modelleme rotası.

To cite this article in APA Style:

Cakmak Gürel, Z. & Işık, A. (2021). An Analysis of Pre-Service Mathematics Teachers' Behavior on Mathematical Modeling Cycle. Bartın University Journal of Faculty of Education, 10(3), 571-585. https://doi.org/10.1016/buefad.871566

1 | INTRODUCTION

Mathematical modelling represents a cyclic process between the real world and the mathematics world (Blum & Borromeo Ferri, 2009). Many researchers describe the mathematical modeling process as a cyclical process (Blum & Leiß, 2007; Greefrath & Vorhölter, 2016; Maaß, 2006; Schaap, Vos & Goedhart, 2011). Mathematical modeling is represented by a cyclic model that includes the real situation, the situation model (the mental representation of the situation), the real model, the mathematical model, the mathematical result and the real result stages (Blum & Leiß, 2007). There are different mathematical modeling cycles in the literature (Berry & Houston, 1995; Blum & Leiß, 2007; Borromeo Ferri, 2006). When modeling cycles are examined (Blum & Leiß, 2007; Borromeo-Ferri, 2006; Lesh & Doerr, 2003; Voskoglou, 2006), many cycles include real situation, mathematical model, mathematical result and real result stages but it has been observed that there are differences according to the situation model and the real model stages. Blum & Leiß (2007) has developed a detailed modeling cycle that includes all these stages (see Figure 1).

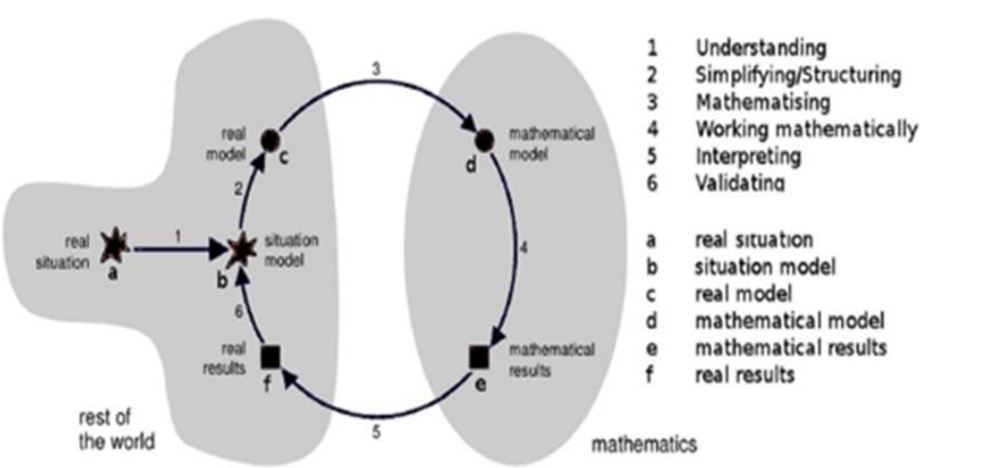

Figure 1. *Mathematical modeling cycle according to Blum & Leiß (2007).*

The mathematical modelling process demonstrated in Figure 1 is defined in six basic stages. These stages are the "Real Situation", "Situation Model", "Real Model", "Mathematical Model", "Mathematical Results" and "Real Results". When the studies on the mathematical modeling cycle are examined, it is revealed that students have problems at all stages of the mathematical modeling cycle (Biccard & Wessels, 2011; Galbraith & Stillman, 2006). In some studies (Blum & Borromeo Ferri 2009; Blum & Leiß, 2007; Borromeo-Ferri, 2010), especially in the transition from the real model to the mathematical model, some studies (Biccard & Wessels, 2011; Gatabi & Abdolahpour, 2013; Ji, 2012), it was determined that students have difficulties in testing the validity.

When the studies on the routes of the students in the modeling cycle are examined, it has been determined that individuals follow a unique path through the modeling process, rather than passing through each stage in sequence (Ärlebäck, 2009; Borromeo Ferri, 2006, 2007; Kehle & Lester, 2003). However, the reasons for their behavior have not yet been explained in detail (Czocher, 2016). Some of the contributing factors are the individual's prior real-world and scholastic experiences, dependence on the perceived purpose for model construction (Matsuzaki, 2011; Stillman, 2000; Thompson & Yoon, 2007) or the students' thinking styles (visual, analytical and harmonic thinking styles) (Blum & Borromeo Ferri, 2009; Borromeo Ferri, 2010; Borromeo Ferri, 2012). The reason why individuals' modeling processes are not linear is because it is a more complex process rather than a simple process like ideal behaviors expressed in modeling cycles (Haines & Crouch, 2010). In this process, individuals usually jump from one stage to the next, go back one step, or repeat the whole process repeatedly. Studies reveal that the modeling cycles of individuals are not linear and move back and forth in this cycle (Borromeo Ferri 2010; 2011; Doerr, 2007; Galbraith & Stillman, 2006). Specifically, Galbraith and Stillman (2001) found that students constantly go back to real-life situations and making assumptions at different stages of the modeling cycle. Similar results were determined in the study by Blum and Borromeo Ferri (2009), and it was observed that one of the students often switched between the real model and the mathematical model. Blum and Leiß (2007) explain this situation in two ways. The first is that reversals are made due to meta-cognitive activities in the verification or validity stages. The second is that students do not fully understand the real-life situation, cannot construct the real model, cannot simplify and structure the given real situation, and thus must return even if it moves in the cycle. Blum and Leiß (2007) also describe modeling processes in which no returns are made. In his study with ninth grade students, he determined that none of the students tried to develop their own solutions and that the students completed the process when they reached any result. This shows that students complete the process when they reach a mathematical result without creating a model.

In the literature about modeling cycles of students, it was seen that the behaviors of students on the modeling cycle were defined as case study (For example, Blum & Borromeo Ferri, 2009; Borromeo Ferri, 2007). In this study, it was aimed to investigate the effect of experience in modeling on individual modeling cycles. It is important to determine changes in individual modeling cycles because of participation in the mathematical modeling learning environment. In this respect, it is thought that the study will contribute to the limited literature on describing behaviors in the mathematical modeling cycle.

The aim of the study is to determine the individual modeling routes of pre-service teachers who participate in mathematical modeling learning environment and who do not. The sub-problems for this purpose are as follows:

1. Which stages of the modeling cycle do the pre-service teachers, who participate in the learning environment and not participate, adequately perform in the pre and post interview?
2. What are the differences and similarities between the behaviors of the pre-service teachers who participate in the learning environment and who do not participate in the modeling cycle in the pre and post interview?

2 | Method

Action research is used in this study. Action research is seen as a systematic process used to solve educational problems, improve educational practices and improve education quality (Carr & Kemmis, 2003; Tomal, 2010). This research design is practice-oriented research rather than research aimed at defining a problem (Elliott, 1991). In action research, while the problem is determined in qualitative ways at the beginning; at the end of the research, data collection is carried out in qualitative ways to understand whether the action plan has been successful and whether there is a difference in the knowledge and skills of the students. In this study, pre-service teachers were interviewed individually before the action plan and their knowledge and skill levels on mathematical modeling were revealed. Then, an action plan was developed and an environment for learning mathematical modeling was planned. In this learning environment, pre-service teachers were provided to work with groups, to be exposed to modeling problems for a long time, and to gain theoretical knowledge about modeling. In addition, evaluation of the solutions of pre-service teachers' weekly modeling activities and the next week's modeling activity was planned by the teacher and the expert. At the end of the 11-week action plan, the last interview was made individually with the pre-service teachers. Mathematical modeling problem was used as pre and post interview (see Appendix 1).

THE STUDY GROUP

The study was conducted with the fourth-grade students of elementary mathematics education undergraduate program. The research was conducted with 17 pre-service teachers participating in the mathematical modeling learning environment and 15 pre-service teachers who did not participate in the learning environment. During their education, they take theoretical and practical courses in the department.

They take theoretical courses such as algebra, statistics, analytical geometry, analysis, general physics, applied mathematics teaching, measurement and evaluation, material design, and problem-solving. These pre-service teachers did not take any courses directly related to mathematical modelling. Since action research involves a long-term practice, it is important that individuals feel willing to participate in the study (Tomal, 2010). In this context, participation and non-participation in the mathematical modeling learning environment is left to the preference of pre-service teachers. Pre-service teachers were informed about this study and were encouraged to participate in the learning environment every week.

Pre-service teachers participating in the learning environment were coded as K1, K2, ..., K17, while those who did not attend were coded as KM1, KM2, ..., KM15.

Data collection

In the study, pre and post interviews were made individually to the pre-service teachers who participated in the learning environment and did not. Modeling problems given in the pre and post interviews are presented in Appendix 1. The research process is summarized in Table 1.

Table 1. Research process

Pre-service teachers not participating in the learning environment	Pre-service teachers participating in the learning environment	Time
Pre interviews (Individually)	Pre interviews (Individually)	1 week
	General information about mathematical modeling	1 week (3 lesson hours)
	Participation in mathematical modeling learning environment	10 weeks (30 lesson hours)
Post interviews (Individually)	Post interviews (Individually)	1 week

Pre-service teachers who did not participate in the learning environment were asked to individually solve the modeling problem given in the pre and post interview. Pre-service teachers who participate in the learning environment were made informative meeting about modeling and modeling activities were carried out with the group for 10 weeks. The problems that exist in the literature such as the big foot problem, the baseboard problem and the traffic intersection problem are used in the study. The action plan is organized as follows: in the first two weeks, activity based on the whole modeling cycle was applied. These activities are suitable for a holistic approach. It has been determined by the expert and the practitioner that the pre-service teachers mostly have problems in creating and solving models. Then, modeling activities for the stages of creating and solving models were applied for four weeks. After it was decided that they had reached a sufficient level, activity based on the whole modeling cycle was applied. Since it was determined that there were problems in the validation phase, the next activity was prepared according to this stage. After this problem, activity based on the whole modeling cycle was applied, and it was determined that there was a problem in creating the real model. The next activity was prepared according to this stage. The process was completed by applying the last activity based on the whole modeling cycle.

The pre-service teachers were asked to individually solve the modeling problem given in the pre and post interviews. To determine whether the change or development in the modeling cycles of the pre-service teachers participating in the learning environment was caused by the applied modeling problem, data were collected from the pre-service teachers who did not participate in the learning environment. The modeling level of pre-service teachers was determined in the pre-interview. Accordingly, it was understood that all pre-service teachers' prior knowledge about modeling was similar. In addition, the fact that the individual modeling routes of the pre-service teachers who did not participate in the learning environment were similar showed that the development was not caused by the modeling problem in the post interview.

The researcher did not direct the participants and it was determined their development and competencies without any intervention during pre and post interview.

Data Analysis

Pre and post interviews of the pre-service teachers were videotaped and working papers were collected. In the study, it was determined to which modeling stage all pre-service teachers progressed correctly. The definitions and indicators of the levels of the mathematical modeling cycle developed by Ji (2012) and adapted to this study are given in Table 2.

Table 2. Levels of the Mathematical Modeling Cycle

Stage	Definition	Indicator
0	Cannot make any connection between real world and math world	Blank or unrelated answers are valued in this category.
1	Understands the real-world situation, forms a mental representation of the situation, but fails to realize the ability to construct, simplify, make assumptions, and predict.	Draws the representation of the given situation, expresses it in words or talks about past experiences, but was unable to construct the real model.
2	Simplifies the real situation, finds the real model, and realizes its relevance to mathematics, but cannot construct the mathematical model or transfer it to the world of mathematics	The individual makes assumptions about the modeling situation, simplifies the situation, determines the variables, and makes predictions about these variables. But he could not mathematize.
3	Creates the mathematical model and turns it into a mathematical problem but cannot solve the model.	Sets up the mathematical model and creates a mathematical problem. But he could not solve the mathematical problem.
4	Solves the mathematical model and gets the mathematical results, but cannot interpret the real world	Solves the mathematical problem and gets mathematical results. But he could not make the transition to real results.
5	It interprets mathematical results to the real world but cannot test their validity.	Can interpret mathematical results and take real-world results, but cannot test their validity
6	It tests the validity of the real results and adapts the model if they are not suitable.	It tests the real-world accuracy and validity of its real results.

Through the coding presented in Table 2, it was determined to what stage all teacher candidates progressed correctly. Sufficient, partially sufficient and inadequate performance sub-dimensions for each stage were created. For example, if the participant determines all the variables that affect the situation in the second stage and can make predictions about these variables, he/she has shown a sufficient performance in the second stage. However, if he/she determines some of the variables that affect the situation and makes only predictions about them or if he/she cannot determine only the variables and make predictions, he/she has partially performed enough in the second stage. If the participant could not determine the variables that directly affect the situation, it was evaluated in the category of inadequate performance. It has been observed that if he/she has never achieved these competencies, he/she cannot make the transition to this stage. In this case, the participant was evaluated in the first stage, which is a sub-stage. it is determined that he has passed to the second stage if he has achieved partially sufficient or sufficient performance.

In addition, the mathematical modeling cycles of pre-service teachers were analysed according to the modeling cycle given in Figure 1. The forward and backward movements of the pre-service teachers in the modeling cycle were determined. Students' individual modeling processes are shown through arrows on the modeling cycle and numbered as 1A, 2B, 3C, 4D, 5E, 6F. While the numbers in the form of 1,2, 3… express the order between the stages; A: the mental representation of the situation, B: the real model, C: the mathematical model, D: the mathematical result, E: the real result, F: the transition to the verification stage. Regardless of the correctly progress of the pre-service teachers in the process, it was determined they switched from which stage to which stage by means of arrows. For example, if a pre-service teacher who created the real model, expressed the real results intuitively and completed the process without obtaining the mathematical model and its results, the individual modeling cycle is shown by an arrow drawn directly from the real model to the real results.

Research ethics

Exempt from research ethics.

3 | Findings

Table 3 shows the findings related to the first sub-problem that is "Which stages of the modeling cycle do pre-service teachers who participate in the learning environment and not participate in the pre and post interviews adequately?"

Table 3. Pre and post interview findings of pre-service teachers who participated in the learning environment of mathematical modeling and who did not.

	Code	Pre-service teachers participating in the learning environment	f	%	Pre-service teachers not participating in the learning environment	f	%
Pre-interview (Filling up Problem)	Stage 0	K3, K4	2	12	KM2,	1	7
	Stage 1	K6, K13	2	12	KM11, KM13	2	13
	Stage 2	K1, K2, K5, K7, K8, K9, K10, K11, K12, K14, K15, K16, K17	13	76	KM1, KM3, KM4, KM5, KM6, KM7, KM8, KM9, KM10, KM12, KM14, KM15	12	80
	Stage 3	-	-			-	-
	Stage 4	-	-			-	-
	Stage 5	-	-			-	-
	Stage 6	-	-			-	-
Post-interview (Bus Stop Problem)	Stage 0	-	-	-	KM3, KM7, KM12	3	20
	Stage 1	-	-	-	KM2, KM11	2	13
	Stage 2	K1, K3, K5, K9, K11, K15, K17	7	41	KM1, KM4, KM5, KM6, KM8, KM9, KM10, KM13, KM14, KM15	10	67
	Stage 3	K12, K6	2	12		-	
	Stage 4		-	-		-	
	Stage 5	K2, K4, K7, K8, K10, K13, K14, K16	8	47		-	
	Stage 6	-	-	-		-	

According to the findings obtained from the pre-interview, it was determined that 76% of the 17 pre-service teachers who participated in the learning environment, 80% of the 15 pre-service teachers who did not participate in the learning environment were able to progress to the stage of creating the real model but could not create the mathematical model. According to the findings obtained from the last interview, it was determined that all teacher candidates participating in the learning environment progressed at least to the stage of constructing the real model. Most of the pre-service teachers (12% + 47% = 59%) have also completed the mathematical model stage. 47% of the pre-service teachers reached both mathematical and real results. It was determined that 67% of the pre-service teachers who did not participate in the learning environment were able to progress to the stage of the real model in the mathematical modeling cycle, but none of them could switch from the real model to the mathematical model.

Figure 2 shows the findings related to the second sub-problem. In addition, individual modeling cycles were given to reveal the behaviors of pre-service teachers in the modeling cycle. While the pre-service teachers participating in the learning environment were described as experienced in mathematical modeling in their last interviews, the pre-interviews of the pre-service teachers participating in the learning environment and the pre and post interviews of those who did not were classified as inexperienced in mathematical modeling.

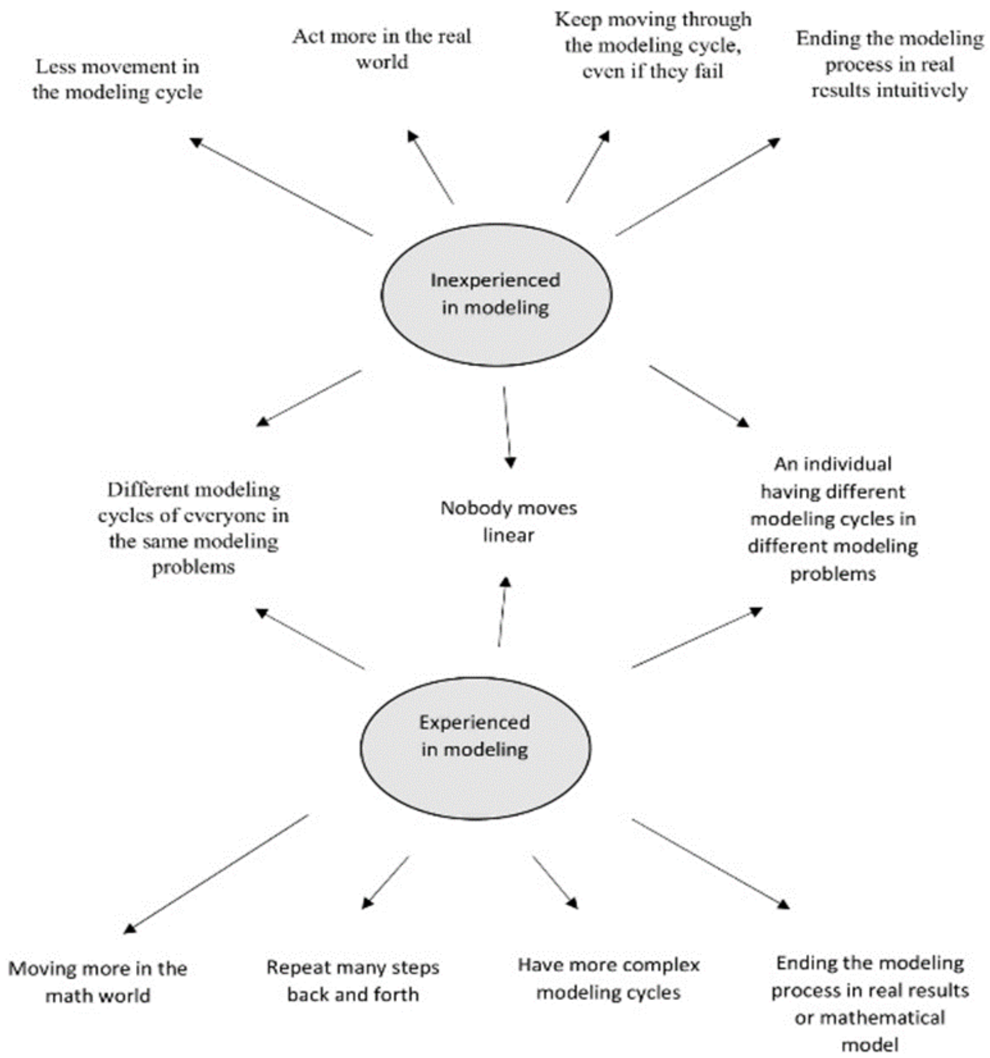

Figure 2. *Similarities and differences in modeling cycles of pre-service teachers who are experienced and inexperienced in mathematical modeling*

When the behaviors in the modeling cycle were examined, it was determined that all pre-service teachers had a nonlinear cycle in the pre and post interviews, each teacher candidate had different modeling cycles in different modeling problems, and each teacher candidate's modeling cycles were different from each other in the same modeling problem. As an example of this situation, the modeling cycles of K10 participating in the learning environment and KM13, which does not participate in the learning environment, belonging to the pre and post interview are presented in Figure 3.

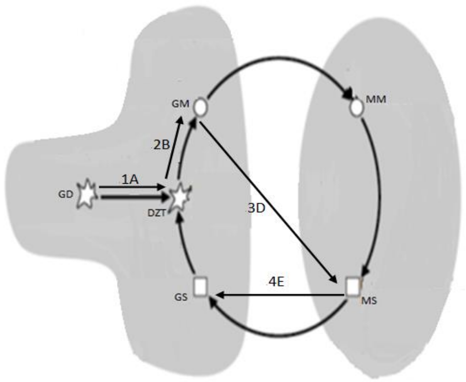

Figure 3a. *K10's individual modeling process for pre-interview.*

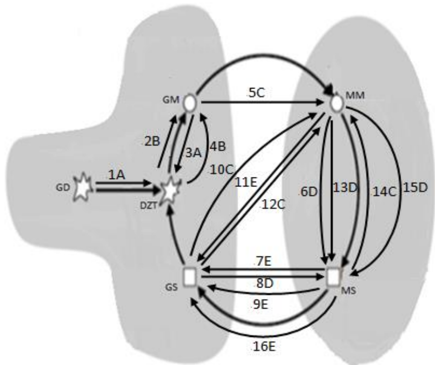

Figure 3b. *K10's individual modeling process for post-interview.*

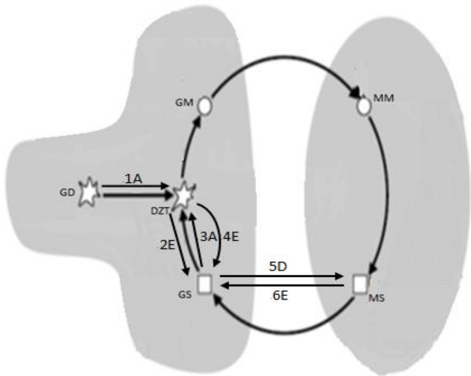

Figure 3c. *KM13's individual modeling process for pre-interview.*

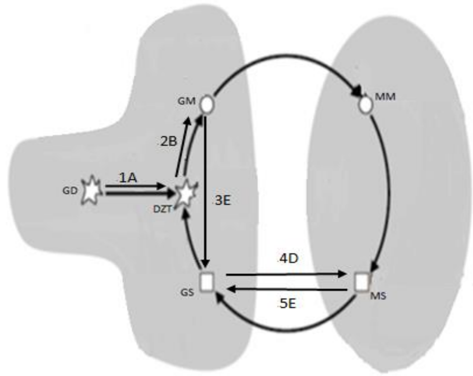

Figure 3d. *KM13's individual modeling process for post-interview.*

When the findings of pre-service teachers experienced in modeling are examined, it was determined that they repeated many steps back and forth in the post interview. When they reached a conclusion, they tried to revise the model, so they had more complex modeling cycles compared to the pre-interview. In addition, it has been observed that they mostly act in the world of mathematics. Even if they express real results, they complete their process in the modeling cycle either at the real results or at the mathematical model stage. As an example of this situation, the modeling cycle of K14 participating in the learning environment of pre and post interview is given in Figure 4.

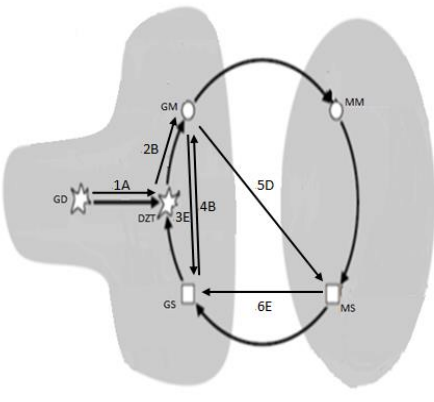

Figure 4a. K14's individual modeling process for pre-interview.

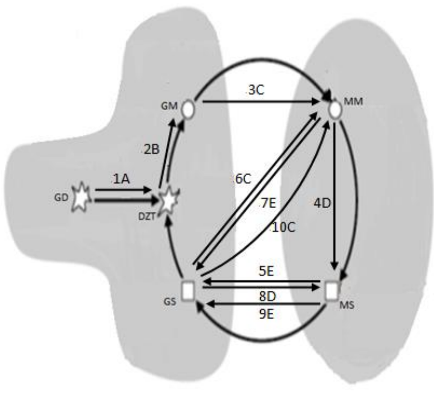

Figure 4b. K14's individual modeling process for post-interview.

Worksheet of K14's pre and post interviews are given in figures 5 and 6.

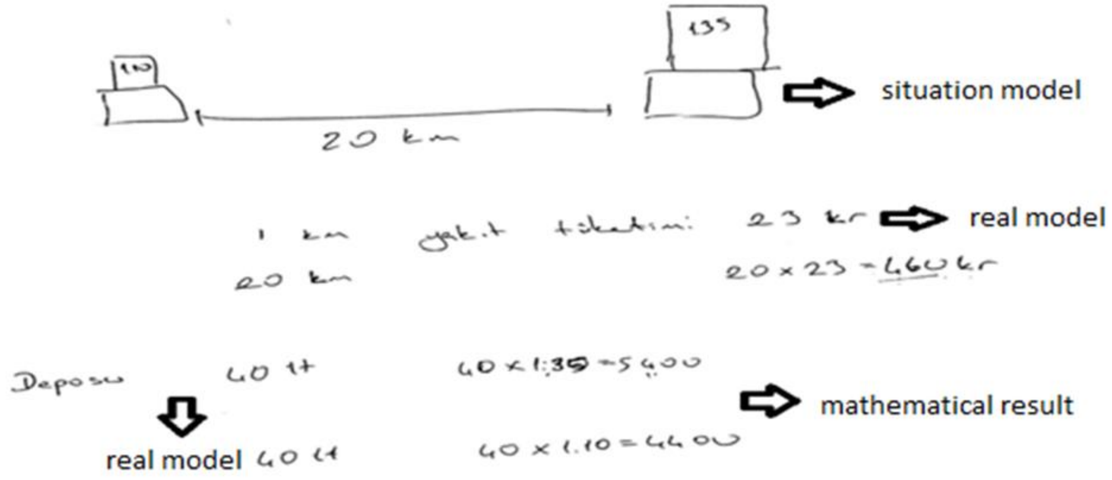

Figure 5. *Worksheet for K14's pre-interview*

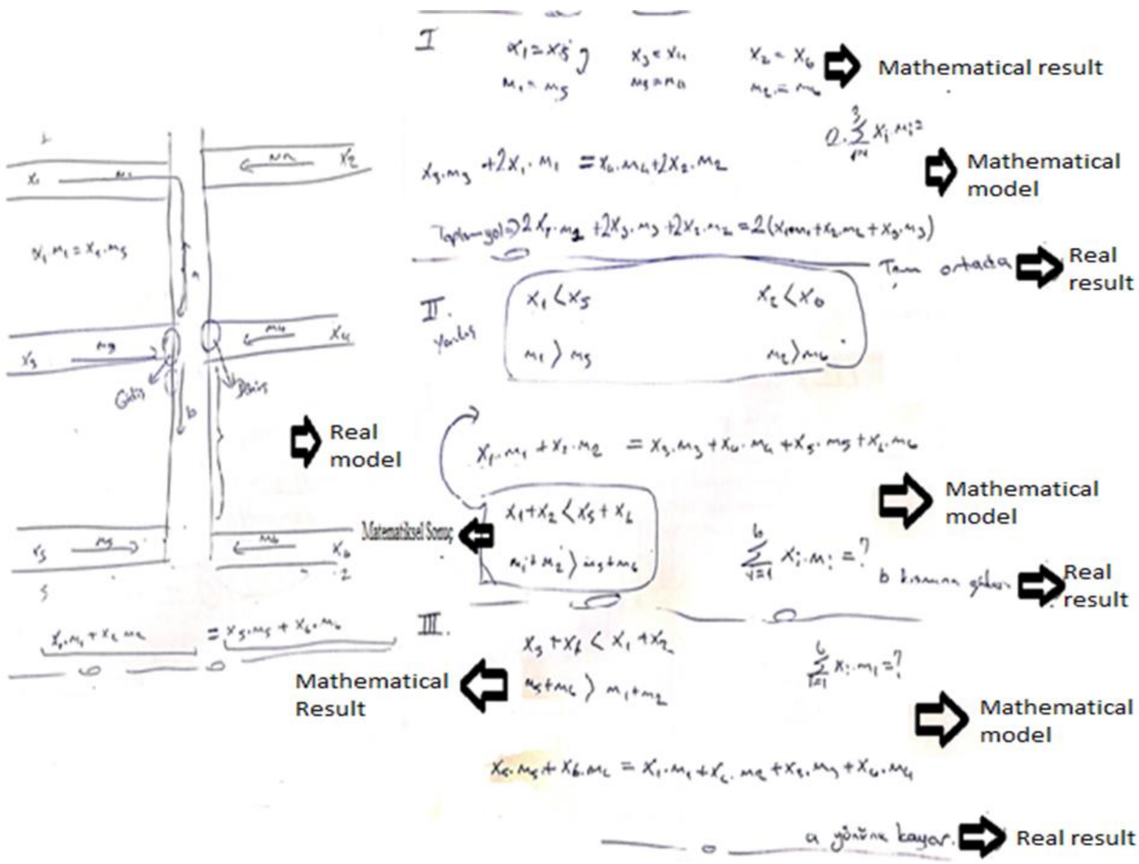

Figure 6. *Worksheet for K14's post-interview*

When the findings of pre-service teachers who are not experienced in modeling are examined, it was determined that they made a direct transition to mathematical results based on any assumptions or guesses without establishing a mathematical model. It has been observed that when they reach a conclusion, they end the process and thus move less in the modeling cycle. It has been found that areas of action are generally in the real world. In addition, it was determined that even if the pre-service teachers failed in understanding the problem and constructing the real model, they continued to act in the process and completed the modeling process intuitively with the real results they reached. As an example of this situation, the modeling cycle of KM2, which does not participate in the learning environment, belonging to the pre and post meeting is presented in Figure 7.

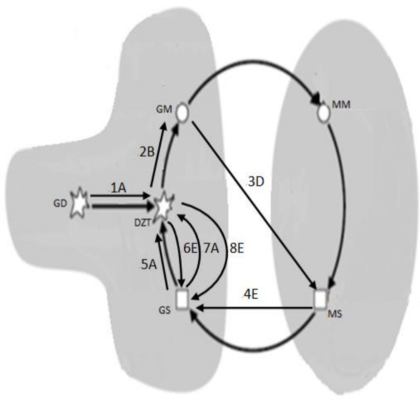

Figure 7a. *KM2's individual modeling process for pre-interview.*

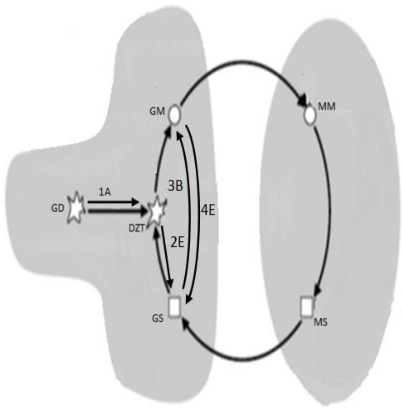

Figure 7b. *KM2's individual modeling process for post-interview.*

Worksheet of KM2's pre and post interviews are given in figures 8 and 9.

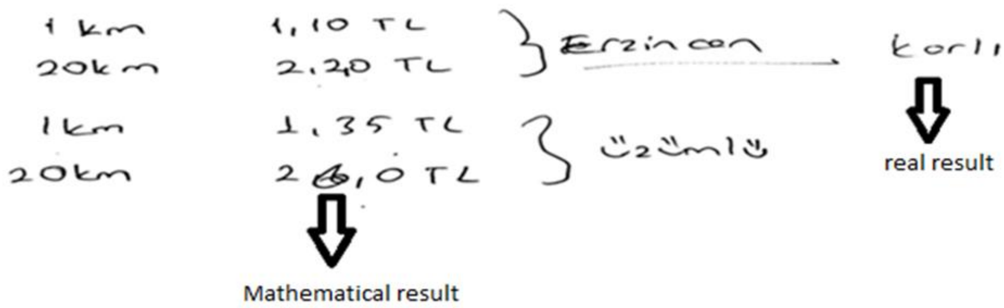

Figure 8. *Worksheet for KM2's pre-interview*

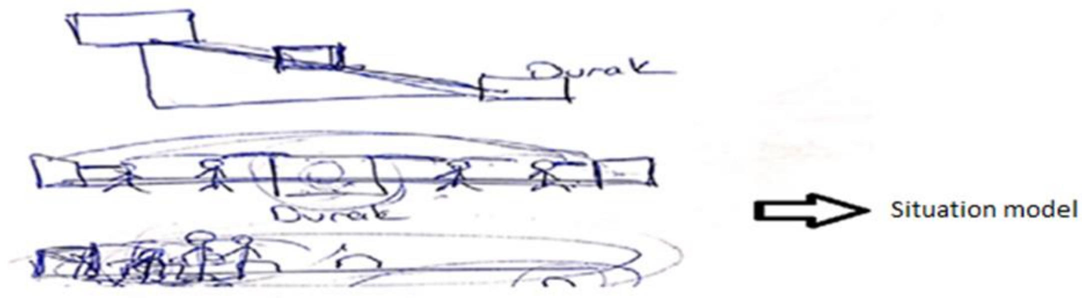

Figure 9. *Worksheet for KM2's post-interview*

4 | Discussion & Conclusion

The aim of the study is to determine the individual modeling routes of pre-service teachers who participate in mathematical modeling learning environment and who do not.

While most of the pre-service teachers who participated in the learning environment reached the real model stage in the pre-interview, it was determined that almost half of them were able to progress until the real results stage in the post interview. Similar results with this study were determined by Ji (2012) and Gatabi and Abdolahpour (2013). It was determined that pre-service teachers who did not participate in the learning environment could only come to the real model stage in both pre and post interviews. This result shows that the development in the modeling cycles of pre-service teachers participating in the learning environment is not random or caused by the given modeling situation. Similarly, studies (Biccard & Wessels, 2011; Galbraith & Stillman, 2006; Gatabi & Abdolahpour, 2013) show that students who are not experienced in mathematical modeling experience problems at all stages of the mathematical modeling process. Especially, Blum and Borromeo Ferri (2009), Blum and Leiß (2007), Borromeo Ferri (2010) and Frejd and Ärlebäck (2011) also identified the problems that occurred during the transition to the mathematical model. Also, Biccard and Wessels, (2011) Gatabi and Abdolahpour (2013) and Ji (2012) determine that students have difficulties in testing the validity of the real result as this study.

When the behaviors of pre-service teachers in the modeling cycle are examined; It has been determined that all pre-service teachers act nonlinear in the modeling cycle. Studies (Borromeo-Ferri 2010; Borromeo-Ferri, 2011; Doerr, 2007; Galbraith & Stillman, 2006; Peter-Koop, 2004) show that students' modeling cycles are not linear. In the study, it was revealed that pre-service teachers have different modeling cycles and solution processes in different modeling situations and that modeling cycles are different from each other individually.

It has also been determined by Ärlebäck (2009) and Czocher (2016) that everyone follows a unique path in the modeling cycle. The reason for this difference was based on the thinking styles of students by Blum and Borromeo Ferri (2009), while Matsuzaki (2011), Stillman, (2000), and Thompson and Yoon, (2007) attributed the differences in individuals' real life and mathematical experiences.

It has been determined that those experienced in mathematical modeling move more back and forth by repeating many steps, move further away from the ideal modeling cycle and have more complex modeling cycles. Borromeo Ferri (2010) explains this situation depending on the thinking styles of the students, and it is revealed that students with analytical thinking structure move more back and forth in the modeling cycle. In this study, this result is explained by participation in the learning environment of mathematical modeling. It was stated by Blum and Leiß (2007) that students who were successful in the mathematical modeling process returned to check the solution or to make critical reflections on the solution of the problem, as they also continued meta-cognitive activities during this process. It was observed that the experienced pre-service teachers in the modeling process mostly moved in the world of mathematics and completed the process in the modeling cycle at the mathematical model stage even if they expressed real results. This is thought to be due to simplifying the mathematical model and revising the mathematical model. Pre-service teachers can also return to the mathematical model stage to show their mathematical model with a different representation.

In this study, it was determined that the pre-service teachers who were not experienced in the modeling process mostly act in the real world. It was determined that these pre-service teachers tended to express real results and they completed their modeling cycles at the stage of real results by interpreting either the mental representation of the situation or the real model intuitively. In addition, they move less in the modeling cycle than those experienced in the modeling cycle. It has been determined that although they move less, they go back and forth between some stages several times in the modeling cycle but complete the process unsuccessfully. Although they failed in the modeling process, they continued to move in the cycle, as stated by Blum and Leiß (2007) that "students should return even if they move through the cycle because they do not fully understand the real-life situation, cannot construct the real model, cannot simplify and structure the given real situation." Blum and Borromeo Ferri (2009) explained the reasons for the return of students who fail in modeling as the students do not fully understand the real-life situation, cannot construct the real model, simplify and construct the given real situation, and thus they must return even if they progress in the cycle. Borromeo Ferri (2010), on the other hand, explains this result with their thinking styles, and states that students with visual thinking style first talk about the real-life situation, have difficulty in transitioning to the mathematical model, perform the ideal modeling cycle more linearly, and cannot complete the mathematical modeling process successfully. In this study, it was observed that pre-service teachers who were not experienced in modeling, regardless of their thinking style, displayed a similar behavior. Pre-service teachers without mathematical modeling experience are not sufficient to complete the stages in the modeling cycle. That is why they cannot move forward in the modeling cycle. They want to end the process immediately. Therefore, it is thought that pre-service teachers without mathematical modeling experience cannot engage in more complex behaviors.

As a result, it was determined that pre-service teachers participating in mathematical modeling learning environment have more successful modeling cycles. It has been determined that the developed learning environment has a positive change on the mathematical model phase. Accordingly, it has also improved the interpretation skills of pre-service teachers. Taking mathematical modeling education causes changes, developments and differences in the modeling cycles. To develop modeling competence, it is recommended to create environments for learning mathematical modeling.

ACKNOWLEDGMENTS

This research article was formed based on the first author's Ph.D. Dissertation.

STATEMENT OF PUBLICATION ETHICS

The authors of the study declare that the research has not any ethical problem and the research and publication ethics were considered in the study.

Researchers' contribution rate

The contribution rate of researchers is equal.

Conflict of interest

There is no conflict of interest in this study.

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Appendix 1.

Pre-interview

"Filling up"

Mrs. Ela lives in Üzümlü, 20 km away from the border of Erzincan in Turkey. To fill up her X she drives to Erzincan where immediately behind the border there is a petrol station. There you must pay 11.0 TL for one liter of petrol whereas in Üzümlü you have to pay 13.5 TL. Is it worthwhile for Mrs. Ela to drive to Erzincan? Give reasons for your answer (Blum & Borromeo Ferri, 2009).

Post-interview

"Bus stop"

When we consider a school bus, there is a need to decide a place of the school-bus shelter for a group of students living along a road. Determine where the shelter should be located so that the total distance the students must walk is the minimum amount (Swetz & Hartzler, 1991)