Educational Sciences: Theory & Practice - 13(2) • Spring • 1187-1192

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The Effect of Instruction through Mathematical Modelling on Modelling Skills of Prospective Elementary Mathematics Teachers*

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Abstract

The aim of this study was to examine the modelling skills of prospective elementary mathematics teachers who were studying the mathematical modelling method. The research study group was composed of 35 prospective teachers. The exploratory case analysis method was used in the study. The data were obtained via semi-structured interviews and a mathematical modelling test. The phenomenographic method and descriptive analysis were used in analysing the data. As a result of the study, it was determined that there was a significant change in the knowledge, skills, and opinions of prospective teachers on mathematical modelling. Therefore, it was considered that it would be appropriate to feature mathematical modelling in the teaching curriculum in universities' faculties of education for prospective teachers to use in their courses.

Key Words

Mathematical Modelling, Elementary Mathematics, Prospective Teachers, Modelling Skills.

Mathematics is a formal language that enables us to express our abstract thoughts as systematic information (MEB [Ministry of National Education]). The ability to understand and utilise mathematics in daily life gains importance, and such importance is constantly increasing. Although it has such an important place in our lives, students have difficulty in learning mathematics, and both fear and anxiety towards mathematics increase day by day. It is stated by the researchers that the three basic reasons for believing mathematics to be difficult are *i)* there is no fairytale share in mathematics, *ii)* to be able to exert mathematical intelligence at any time constitutes a problem (Kart, 1996) and *iii)* mathematics educators do not sufficiently internalise the concepts that they will teach (Işık, 2007).

One of the objectives of mathematics instruction is to raise individuals that can generate effective solutions in problem situations; that can efficiently utilise mathematics that they learn in their daily lives; that are aware of the close relationship between mathematics and the real world; and accordingly that enjoy and love mathematics instead of hating it (Doruk, 2010). Therefore, the aim of mathematics instruction is to earn the student the mathematical knowledge and skills required by daily life; teach him/her how to solve problems; and earn him/her a way of thinking that deals with the situations in the scope of the problem solving approach. To be able to transfer what is learned in daily life in this way of thinking is one of the most significant problems (Altun, 2002a).

* This study includes a part of a Ph.D. thesis by Alper Çiltaş.

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The importance of mathematical modelling, which is defined as the process of overcoming daily life problems (Blum & Feri, 2009) and which basically interprets daily life problems, has increased in recent years. One of the most important reasons for this condition is that researchers in many countries have begun questioning the degree to which the students, who are being raised in their schools, are prepared for solving the daily life problems that they encounter outside school and that they will come across in the upcoming stages of their lives in parallel with the results of international comparative studies such as TIMSS and PISA (English, 2006). In line with this viewpoint, basic knowledge, which is necessary for the entire lives of the individuals, is possible with raising individuals that are comfortable with technology; that can draw interdisciplinary relationships; that have model forming skills; and that can solve problems instead of memorising the operations (Thomas & Hart, 2010). Since mathematical concepts have abstract qualities by their nature, it is important to start with concrete examples and models in order to teach these concepts. Niss (1989) emphasises that mathematical modelling applications increased creative problem solving behaviours, activities and skills among students.

The stages in the mathematical modelling process are composed of understanding the problem, choosing the variables, forming the model, solving the problem and implementing the problem into real life. These stages are in contact with each other and do not have to follow a linear order. For instance, the individual who could not form the model may want to go back to the stage of understanding the problem and re-examine it. A person, who is having difficulty at the stage of solving the problem may go back to the stage of choosing the variables and redefine the variables. According to Doerr (1997), these stages do not have to occur in any order. In every stage, students criticise form their own models and go back to the problem situation. Voskoglou (2007), in a way similar to Doerr, expresses mathematical modelling stages again in five main stages that begin with S1 and end with S5.

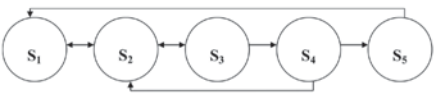

Figure 1.
Mathematical Modelling Diagram

S1: Understanding the problem: Realizing the requirements and restrictions of the daily system, and understanding the statement.

S2: Mathematizing: Formulation of the real situation in such a way that it will be ready for mathematical treatment and the construction of the model.

S3: Solution of the model: Performing mathematical operations.

S4: Control of the model: Reproducing, through the model, the behaviour of the actual system under the conditions existing before the solution of the model.

S5: Interpretation: Interpretation of the mathematical result in order to respond to the actual problem.

According to Spanier (1992), mathematical modelling, which dates back to 1972, first started to be given in the Claremont Mathematics Clinic. He states that a mathematician is trained in this clinic as an individual who overcomes various problems in engineering and physics. Consequently, mathematical modelling began to be included in mathematics and other fields, and various studies have been conducted that span through our time. Although mathematical modelling is used more in physical science and engineering fields, it has gained a significant place in mathematics courses in the last decade.

English and Watters (2004) revealed that the modelling activities that they performed with elementary school students developed the students' mathematical thinking and problem solving skills more than traditional problem solving activities. In a similar study that was applied to approximately 300 students in two different elementary schools for a duration of three years, Boaler (2001) performed mathematical modelling instruction on a group of the students while performing instruction with traditional methods on the other group of the students. At the end of the study, the success of the students who took education via mathematical modelling was found to be higher than that of the students who took education via traditional methods. In another study conducted at elementary level, Olkun, Şahin, Akkurt, Dikkartin, and Gülbağcı (2009) examined the modelling and generalisation process of 3rd, 4th and 5th grade students while solving a non-routine verbal problem. At the end of the study, they observed that the success levels of the students were noticeably low, and a considerable improvement was experienced only in the 5th grade students as a result of an experimental intervention. As a matter of fact, Ikeda, Stephens, and Matsuzaki (2007) requested students to give answers to the questions "What is the mathematical model?", "Is it hard or easy to make a mathematical model?" before and after performing mathematical modelling activities. All of

the students who participated in the study stated that it was difficult to make a mathematical model both before and after the application.

Doruk and Umay (2011), who examined the effect of mathematical modelling activities on the development of students' ability to transfer what they learned in mathematics courses into daily life, determined that the levels at which the groups in which mathematical modelling activities were used benefited from mathematics in solving the problems that they encountered it in their daily lives, and those who used mathematical language and associated mathematics with daily life were higher than those of the groups in which these activities were not used. Eraslan (2011), who aimed to reveal the stages of model forming, attempted to set forth his opinions on the model forming activities of prospective elementary school teachers and the effect of these activities on mathematics learning. According to the obtained results, prospective teachers put forth benefits and restrictions as well as hardships by expressing (a) the indefiniteness of model forming activities, (b) positive contributions to mathematics learning by these activities, (c) usability of these activities in elementary level and other levels and (d) the ways in which they are used effectively.

According to Blum and Feri (2009), although mathematical modelling is one of the most important fields on which mathematics instruction has focused in recent years, it is still not given much importance and is not applied. The fact that modelling is considered to be difficult by both students and teachers is considered to be one of the most important reasons for this condition. As a matter of fact, Çiltaş, Deniz, Akgün, Işık, and Bayrakdar (2011) conducted a study with the participation of 11 elementary mathematics teachers who were working at 11 schools in order to examine the opinions of elementary mathematics teachers on mathematical modelling. Upon analysis of the data, it was found that the teachers who were interviewed and observed in the class did not have enough knowledge about mathematical modelling; also confused the concepts of model, modelling, mathematical model and mathematical modelling; and did not use mathematical modelling in their courses.

According to Umay (2007), mathematics is a part of life, sometimes a key, sometimes a game and entertainment for the "learner" that sees patterns; that draws the relationships; that the reason behind what he/she has discovered; that knows how to behave; and that makes decisions by himself/herself. Therefore, in mathematics instruction, the main principles must be to make the students realise the problem or need; make the students contemplate how to find a solution; and make the student find the exit on his/her own if he/she can.

The aim of mathematics instruction is to earn the person the mathematical knowledge and skills required by daily life; teach him/her how to solve the problems; and earn him/her a way of thinking that deals with the situations in the scope of problem solving approach (Altun, 2002b). Mathematics course teaching curriculum, which was developed and renewed in 2005 by the Ministry of National Education [MEB], embraced the aim to teach mathematical thinking system, structure basic mathematical skills and abilities, which are based upon these skills, in accordance with real life problems. In order to achieve this objective, learning-teaching environments, which were to validate these aims, were added to the curriculum components and organised (Sağırlı, 2010). The vision of the elementary mathematics curriculum has been rearranged in 2005 so as to raise individuals that can utilise mathematics in their lives as necessary; that can form the relation between real life situations and mathematics; that can generate different ways to solve the problems that they encounter; that can think analytically; and that have skills such as reasoning and associating (MEB, 2005). In this regard, the teachers who will earn our students these abilities must be able to apply mathematical modelling in a successful manner.

Method

Research Model

The exploratory case analysis method was used in this study, which is conducted in order to determine mathematical modelling developments of the research group students who are studying with the mathematical modelling method. The exploratory case analysis method is used before conducting large-scale research. Exploratory case study assists in defining the questions, selecting measuring tools, and developing the scales when there is an indefinite condition about curriculum operations, objectives, and results (Davey, 1991).

Research Group

The research group was composed of 35 prospective teachers who were studying as third-year students at the Department of Elementary Mathematics Teaching in the 2010-2011 academic year.

Data Collection

Different classifications were made in the literature, and "interview types" were explained (Çepni, 2007). However, classifications, which are made as structured, semi-structured and non-structured, are generally accepted. Questions were prepared beforehand in semi-structured interviews although there was potential to change the order of the questions and explain in more detail (Karasar, 2009). The semi-structured interview type was selected for this study, since the questions were prepared beforehand. Interviews were conducted one-to-one in a suitable environment where prospective teachers could comfortably express their knowledge, feelings and opinions. Benefiting from Keskin (2008), a mathematical modelling interview form, which was composed of six questions, was prepared for the prospective teachers. After interview form questions were prepared, the validity of the questions was tested by benefiting from expert opinion. Prospective teachers were asked to answer the interview questions sincerely. 10 prospective teachers voluntarily participated in the interviews. These 10 prospective teachers were interviewed again after this study. Interviews lasted for 40-50 minutes on average for each prospective teacher.

Mathematical Modelling Test: A Mathematical Modelling Test [MMT], which was composed of eight questions and oriented towards the concepts that are featured in these subjects, was prepared for 35 prospective teachers (Research Group) who had taken the Analysis-III course in which sequences and series unit is included. MMT questions were prepared and posed to students who had taken the Analysis-III course that was offered in summer school. The MMT was evaluated by two experts. The Pearson Correlation Coefficient (moment-multiplication correlation coefficient) among the total scores of the prospective teachers was found to be 0.72. The reliability of the MMT was tested. Two course hours (100 minutes) were allocated to the prospective teachers for the MMT test.

Data Analysis

The interviews were analyzed by the phenomenographical method. According to Marton (1994) and to Marton and Booth (1997), phenomenographic method is used in research learning differences and the reasons for these differences.

In this study, the mathematical modelling test was evaluated using the analytic-graded grading key, which was prepared by Keskin (2008), by taking modelling processes into account. Each question had a value of 10 points. The total score of the test was determined to be 80. The data that were obtained after the study were evaluated by two experts. Each question was presented as tables.

Application

Mathematical modelling pre-test and interviews regarding the mathematical modelling pre-test was applied to 35 prospective teachers who were studying as third-year students at the Department of Elementary Mathematics Teaching in the 2010-2011 academic year. After pre-tests were applied, instruction with the mathematical modelling method was given to the research group for four weeks in a total of 42 course hours. Course books used were prepared in accordance with mathematical modelling method by benefiting from the source books of Balcı (2008), Dönmez (1985), Kadıoğlu and Kamali (2009) and Stewart (2003) with regard to the subject content.

Results

This section presents the data obtained in the research and findings regarding the success and skills of prospective teachers in the mathematical modelling test using the stated methods and techniques. Each question was evaluated with the MMT grading key in accordance with the codes composing of the names and last names of prospective teachers. Consequently, it was observed that the pre-test score of the students in the MMT were 25.35, whereas the post-test score reached 72.85 and nearly tripled.

In the conducted interviews, mathematical modelling was defined as 'result', 'model forming' and 'formula'. When the answers given to this question by the participants are taken into account, it can be stated that they have not been able to fully express the definition of mathematical modelling, "mathematical modelling" expression as defined by Berry and Houston (1995) and Moscardini (1989). In the last interview conducted with the participants, mathematical modelling was defined as 'the process of overcoming daily life problems', 'model forming' and 'guessing'. They expressed the definition of mathematical modelling as appropriate to the definition of "mathematical modelling" expression that is found in the literature.

Conclusion, Discussion and Suggestions

The primary aim of this study was to examine the effect of instruction through mathematical modelling on the modelling skills of prospective elementary mathematics teachers. Mathematical modelling pre-tests and post-tests as well as pre-interviews and post-interviews were applied to the research group in order to explain the research problem. The percentages of the scores taken from mathematical modelling tests, which were applied on the students at the beginning and end of the study process, were identified, and these were presented both in question form and generally as tables.

It could be stated that the research group were unable to solve the questions in the MMT before the study. In other words, the students experienced difficulty with the questions featured in the pre-MMT as in the study of Lange (1989). It was observed that the majority of the students fulfilled the stage of understanding the problem, which is among the stages of mathematical modelling, in this test that was conducted without giving information to the students. It could be stated that the students accomplished this due to their problem solving skills. That is to say, it could be argued that the students used the stage of understanding the problem, which is the first stage in the problem solving stages of Polya (1957), in pre-MMT. It might be stated that the students generally experienced difficulty in the stages of forming the model, formalising the model mathematically, solving the model, and interpreting the model which are among the mathematical modelling stages expressed by Berry and Houston (1995), Moscardini (1989). This result also corresponds with the study of Eraslan (2011). It can be stated that the research group students were more successful in the questions featured in the post-MMT at the end of the application compared to the mathematical modelling pre-test as in the study of Ikeda et al. (2007). It could also be argued that the research group students experienced difficulty in interpreting the solution to daily life in the post-MMT. This result corresponds with the study of Güzel and Uğurel (2010).

As expressed by Akman, Yükselen, and Uyanık (2000) in their research, it was found that before the application some of the students had the opinion that mathematical modelling must be included in the mathematics teaching curriculum. As expressed by Lange (1989), Moscardini (1989), Reusser and Stebler (1997) and Spainer (1992) in their studies, it was discovered that after the application all of the students had the opinion that mathematical modelling must be included in the mathematics teaching curriculum. As in the research conducted by Lange, research group students expressed before and after the application in the research that they would use mathematical modelling in their courses.

It is considered that it will be appropriate to feature mathematical modelling in the teaching curriculum in universities' faculties of education for prospective teachers to use in their courses because it has been found in view of this study that there is a necessity for an instruction oriented towards developing mathematical modelling skills of prospective teachers in teacher training curricula with the assumption that teachers need to have the competence required by this approach in order to use modelling activities. Furthermore, the studies conducted by Keskin (2008) and Kertil (2008) support this suggestion. Mathematical modelling must be given in each university-level course and mathematical modelling must be given to students to help them to solve the problems that are appropriate to the respective course. It is suggested that mathematical modelling must be included in the related curricula of faculties of education as an elective course.

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Ek 1.

Matematiksel Modelleme Mülakat Formu

Adı ve Soyadı: No:

Tarih ve Saat: Yer:

Sevgili öğrenciler bu form model ve modelleme, matematiksel model ve modelleme hakkında sizlerin görüşlerini almak amacıyla hazırlanmıştır. Sizden istenilen aşağıdaki soruları içtenlikle yanıtlamanızdır. Araştırma sonucunda elde edilen veriler, dizi ve seri kavramlarının matematiksel modelleme ile anlatımına yönelik öğrenmelerle ilişkili çalışmalarda kullanılacaktır. Mülakatlar kayıt altına alınacaktır. Mülakat süresi yaklaşık olarak 40-50 dakika olacaktır. Katkılarınızdan dolayı teşekkür eder, başarılar dilerim.

Mülakat Soruları

1. Model nedir? Modelleme nedir?
   - ► Matematiksel model ifadesinden ne anladığınızı açıklar mısınız?
   - ► Matematiksel modellemeden ne anladığınızı açıklar mısınız?
2. Matematik eğitiminde günlük hayat problemlerinin kullanılması hakkında ne düşünüyorsunuz?
3. Matematik öğretim programında günlük hayat problemlerine yer verilmesi hakkında ne düşünüyorsunuz?
4. Siz öğretmenlik yaparken günlük hayat problemlerine derslerinizde yer vermeyi düşünüyor musunuz? Neden?
5. Size günlük hayatla ilgili veriler verildiğinde ve bu verileri kullanarak bir problemin çözümü istendiğinde nasıl bir yol izlersiniz?

Gelecekte günlük hayatla ilgili bir durumu tahmin etmeniz istense neler düşünürsünüz?

Ek 2.

Matematiksel Modelleme Testi

Sevgili öğrenciler sizden istenilen aşağıdaki soruları yanıtlamanızdır. Araştırma sonucunda elde edilen veriler, matematiksel kavramların öğretimine yönelik çalışmalarda kullanılacaktır. Teşekkürler…

Adı-Soyadı:

Numarası :

1. Bir çoban beslediği 40 tane koyununu padişaha hediye etmek için saraya gider. Padişah, çobana sen kimsin de sadece 40 koyunu bana hediye olarak veriyorsun. Koyunların ağırlığı kadar sana altın veririm der ve çoban ile alay eder. Çoban koyunları hediye değil de parasıyla almak isteyen padişaha satmayı kabul eder. Padişahım koyunları sana satacağım ama benim belirleyeceğim fiyattan alacaksınız der ve padişah da bunu kabul eder. Çoban padişaha; birinci koyunu 1 lira, ikinci koyunu 2 lira, üçüncü koyunu 4 lira, dördüncü koyunu 8 lira olacak şekilde hepsini alacaksın der. Padişah yine gülmüş, emin misin demiş. Çoban evet değince padişah kabul etmiştir.

Yukarıdaki problemde çobanın onuncu, yirminci, otuzuncu ve kırkıncı koyunlardan ne kadar para alacağını hesaplayınız?

2. Beril evinde doğum günü partisi vermek istemektedir. Beril doğum günü partisine birinci kapı zili açıldığında 1 kişi, ikinci kapı zili çalındığında 2 kişi, üçüncü kapı zili çalındığında 3 kişi gelecek şekilde arkadaşlarını partiye davet etmektedir. Beril'in partisinde toplam 55 kişi olduğuna göre kapı zili kaç kez çalınmıştır?

3. Bir tür yılan bir aylık olunca gövdesinde bir siyah halka beliriyor. Daha sonraki her ay bu siyah halkanın ortasında bir kırmızı halka beliriyor ve böylece iki siyah bir kırmızı halka oluşuyor. Takip eden aylarda bu değişim aynı şekilde sürüyor. Yani her siyah halka, ortasından bir kırmızı halka ile bölünüyor. Buna göre; bir yaşındaki bir yılanın kaç siyah, kaç kırmızı halkası olduğunu bulunuz?

4. Bir bisikletli 841 km olan Erzurum-Ankara yolunu gitmek istemektedir. Sürücü hareketine sabah saat 8.00 başlayıp hiç durmadan devam etmiştir. Sürücü yolu tamamlayacak şekilde bir saat içerisinde 1 km, sonraki bir saatte 3 km, daha sonraki bir saatte 5 km yol alacak şekilde her bir saatte 2 km arttırarak hareket etmektedir.

Belli bir km ye geldiğinde ise aynı şekilde azaltarak son saatte alacağı yol 1 km olacak biçimde seyahatini planlamaktadır. Sürücünün saat kaçta Ankara'da olacağını bulunuz?

5. Yeni işe başlayan bir memur ilk maaşının tamamını bir bankaya birikim amaçlı olarak yatırıyor. Takip eden ayda ise maaşının yarısını, diğer ayda ise maaşının üç'te birini(1/3), daha sonraki aya dörtte birini(1/4) yatırıyor. Bu şekilde bankaya para yatırmaya devam ediyor. Bir an için bu memurun sonsuza dek yaşadığı düşünülürse; bankada toplam kaç para biriktirebilir?

6. "Zenon Paradoksu: M.Ö. 450'li yıllarda yaşamış olan filozof Zenon; hareketli bir cismin bir noktadan başka bir noktaya gidebilmesi için önce aradaki mesafenin yarısını, daha sonra da kalan mesafenin yarısını kat etmesi gerektiğini söyler. Cisim bu durumda sonsuz kez yarı mesafe kat edeceğinden, hiçbir zaman diğer noktaya ulaşamayacaktır". Bu paradoksa göre doğru görülen bu ifadenin geçersiz olduğu matematiğe sonsuzluk kavramı girdikten sonra anlaşılmıştır. Belirli bir limit değerine yakınsayan ve geometrik dizi oluşturan terimlerin toplamı (sonsuz geometrik seri) bulunabildiğinden beri bu paradoks geçerli değildir. Bu paradoksu dikkate alarak aşağıdaki problemi yanıtlayınız.

Bir çiftçi kenarı 1 km olan kare şeklindeki tarlasını her yıl parça parça satmaktadır. Tarlasını, alanı sonsuz bir dizinin toplamı olacak şekilde; önce yarısını, tekrar kalan kısmın yarısı şeklinde satışa sunmuştur. Bu şekilde satışa devam eden çiftçinin sattığı toplam alanı bulunuz?

7. Elinde 1 Türk Lirası olan Ali, yıllık %50 bileşik faiz (yılsonundaki faizin anaparaya eklenmesi) uygulayan bir bankaya parasını yatırmıştır. Buna göre; k yılsonunda Ali'nin toplam kaç parası olacağını bulunuz?

8. Hileli bir şans oyununa katılıp gerekli olan 190 TL kazanmak isteyen bir adamın oyun sayıları ve bu oyun sayısına karşılık gelen para miktarı şu şekildedir. Birinci oyunda 1 TL kazanıp ikinci oyunda 4 TL kaybediyor. Üçüncü oyunda 9 TL kazanıyor, Dördüncü oyunda 16 TL kaybediyor ve bu şekilde oyun devam ediyor. Bu adam gerekli olan parayı kazanabilir mi? Eğer kazanabilir ise kaçıncı oyunda kazanabilir?