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COMPARING OF MATHEMATICS TEACHERS CANDIDATES' MATHEMATICAL MODELLING SKILLS: TURKEY AND ENGLAND SAMPLES

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Abstract:
This study aims to compare mathematical modelling abilities of prospective mathematics teachers. 38 Turkish prospective mathematics teachers studying at the Department of Primary Mathematics Education and 26 English prospective mathematics teachers studying at Initial Mathematics Teacher Education Program of the Graduate School of Education attended the study. Two mathematical modelling problems were given to the students. The stages of mathematical modelling given by Berry and Houston (1995) were used to examine the participants' mathematical modelling abilities. What the Turkish and English students did in each of these stages was presented separately for both problems categorically and with the percentage tables and to what extent the students were successful in these stages was shown. The achievement scores of Turkish and English students were compared with independent groups t-test. The results showed that almost all of the participants were quite inadequate especially at the point of setting the mathematical model. This result indicates that mathematics teacher candidates had difficulty in transferring algebraic concepts such as function, equation, inequality to real-life problems. On the other hand, it can be said that English participants' abilities were better than that of Turkish participants.

Keywords: mathematical modelling; modelling competency; prospective mathematics teacher

1. Introduction

Mathematics is a systematic way of thinking that produces solutions to real life problems through modelling. Modelling and applications have been an increasingly

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important topic in mathematics education during the last two decades (Houston 2005; Kaiser 2005; Kaiser, Blomhoj & Sriraman, 2006). Mathematical modelling covers the whole process from the beginning of understanding the original real problem until making assumptions by using a model. Modelling is also used to refer to the relationships between results of assumed or experienced empirical knowledge (Berry & Houston, 1995). In this context, "modelling" may be a formula, a table of value or a graph.

Mathematical modelling competencies have been defined as the ability to identify relevant questions, variables, relations or assumptions in a given real world situation, to translate this into mathematics and to interpret and validate the solution of the resulting mathematical problem in relation to the given situation (Blum, Galbraith, Henn and Niss, 2007). The stages in the process of mathematical modelling given by Berry and Houston (1995) which are used in the current study are; understanding the problem, selecting necessary variables, setting a mathematical model, solving the mathematical model and interpretation the model for the real world.

Modelling is inseparably linked with other mathematical competencies such as reading and communicating, designing and applying problem solving strategies, or working mathematically such as reasoning, calculating, etc. (Niss, 2003). The PISA-2006 results revealed again that students all around the world have problems with modelling tasks. Analyses carried out by the PISA Mathematics Expert Group showed that the difficulty of modelling tasks can indeed be substantially explained by the inherent cognitive complexity of these tasks; that is by the demands on students' competencies.

Students' performances in the modelling process could be affected by teaching approach, situation-content, teacher (Niss, 2001), their motivations (Niss, 2001, Tanner and Jones, 1995), previous experiences (Niss, 2001; Klymchuk and Zverkova, 2001) and inadequate mathematical knowledge (Erdoğan, 2010; Zeytun, Çetinkaya, Yıldırım and Erbaş, 2009). In addition, many studies have showed mistakes that occur when learners model problems: Learners have difficulties in creating a connection between reality and mathematics, as well as simplifying and structuring the reality (Hodgson, 1997; Christiansen 2001; Haines, Crouch, & Davis 2001) and problems dealing with the mathematical solution (Hodgson 1997; Haines, Crouch, & Davis 2001). Blum and Ferri (2009) determined that students had difficulties in the stages of "simplifying the problem" and "verifying the model" in the mathematical modelling process. The results of a study carried out by Zeytun, Çetinkaya, Yıldırım and Erbaş (2009) revealed that pre-service teachers faced several difficulties during the modelling process. For instance, students did not attend to the verification step of the modelling process, they had inadequate mathematical knowledge, especially on transition between proportion and equation, interpreting graphs of functions, and graphing skills.

Tanner and Jones (1995) point out that motivation is an essential part of modelling competencies and also knowledge alone is not sufficient for successful modelling as the student must also choose to use that knowledge, and to monitor the process being made. Erdoğan (2010) revealed that students had difficulties using the concept of function significantly by solving modelling problems. According to Erdoğan, students perceive a function only as a relation between two sets, they cannot decide whether the given situation given would be represented with a function and cannot approach through the perspective of relation among variables.

2. Methods

38 Turkish prospective mathematics teachers (28 females, 10 male) studying at the Department of Primary Mathematics Education and 26 English prospective mathematics teachers (12 females, 14 male) studying at Initial Mathematics Teacher Education Program of the Graduate School of Education attended the study. The ages of the participants were between 21 and 24. The education at this school takes 2 semesters. This school was for the graduates who have been successful in studying advanced mathematics, and want to be mathematics teacher.

In this study, two mathematical modelling problems were asked to the students (at the end of the article). Considering that the students had not attended any courses on mathematical modelling before, the problems were designed carefully so as not to be too complex for the students and to require higher mathematics knowledge. The solutions of the problems used in the current research require knowledge of arithmetic, function, ratio, graphic, linear equation, and first-degree inequality in two variables at the basic level. When considered that all the participants took many mathematics lessons such as General Mathematics, Geometry, Linear Algebra, Analysis, Analytical Geometry, Algebra, it is obvious that the participants have the required pre-knowledge. On the other hand, the participants were said what a mathematical model was before they started to solve the problems.

The students' solutions were analysed using the descriptive method. In addition, independent t-test was conducted to compare the results. Therefore, the study has a mixed research design. In order to examine the students' modelling performances, the study employed the stages of "understanding the problem", "selecting the necessary variables", "setting the mathematical model", "solving the mathematical problem", "interpretation the solution" in the process of mathematical modelling given by Berry and Houston (1995). The criteria for these abilities were developed as stated below:

A. Understanding the problem

Very good: Producing a two-variable formula containing the distances in urban and extra urban as variables. These distances should indicate kilometers needed to recover the average difference between the prices of diesel and gasoline cars as buying a diesel car is more economical. Then, it is needed to interpret the formula in terms of both variables together.

Good: Finding a two-variable formula containing the distances mentioned above, but not interpreting. Besides, setting an interactive excel program but not interpreting the solution of the problem in general. In this programme, the person is asked to enter some knowledge. Therefore, this case is personal and not for general solution.

Partially: Finding the distances mentioned above separately.

Poor: Finding the distances mentioned above separately for a specific car model.
Very poor: Finding the total cost (fuel cost and car price) considering a specific km for a specific car model or finding fuel consumption or difference of fuel consumption at 100 km of diesel and gasoline cars in urban or extra urban driving.

B. Selecting the variables

The variables to be used are the total urban "x" and extra urban "y" kilometers to be driven for it to be more economical to buy a diesel car. If no variable was chosen, the students' ability of selecting the variables was considered as "unsuccessful"; if the urban and extra urban kilometers were taken into consideration, it was evaluated as "successful". For the population problem, it is obvious that the variable is time.

C. Mathematical model

For the diesel-gasoline problem, the model is

$$0{,}1498x + 0{,}0755y > 4500$$

If the two-variable formula on the basis of average values is correct or not correct because of some unimportant arithmetic errors, or if a graph that shows the needed urban and extra urban kilometers to be driven together to recover the average price difference between diesel and gasoline cars was drawn, this model was evaluated as "successful". If the two-variable model is for some specific car models, or if an interactive Excel programme was composed, it was evaluated as "partially successful". If only arithmetic was done to find urban and extra urban kilometers separately, these students were evaluated as "unsuccessful".

For the population problem, as setting only one model is not possible and the formula is not known, the students' models were evaluated in terms of acceptability of the results by comparing with the predictions of UK National Statistics. If a student produced a formula by himself/herself and the results obtained are close to the predictions of UK National Statistics, this model was evaluated as "successful". If the model (formula) was produced with the help of a computer programme, or if the results were obtained on the basis of a graph (whether by the help of a programme or by hand) and also the model produced acceptable results then, these students' modelling performances were evaluated as "partially successful". If the model did not produce acceptable results, these students' modelling performances were evaluated as "unsuccessful". Mathematical ability is important in terms of mathematical modelling ability. As the Turkish students did mathematical work in this question to produce a formula, while the English students used Excel and this process is quite simple, the only thing to do is to decide which curve fits best to the given data. The formula is produced by the programme. Therefore, it was important to determine whether the formula was produced by a computer or not.

D. Interpreting the model

In order to interpret the model, a graph might be drawn as follows.

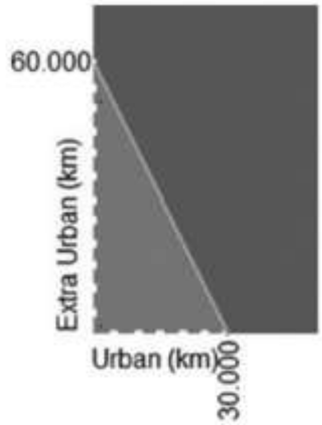

Figure 1: Interpreting the mathematical model as graphic

According to Figure 1, if the point of intersection of the total urban and extra urban kilometers to be driven is on the dark area, it is more economical to buy a diesel car. If the model was interpreted in terms of both urban and extra urban distances together in general meaning by drawing a graph, this interpretation was evaluated as "successful". If the model was interpreted in terms of urban distance and extra urban distance separately or if a student said something like "the person can decide which car is appropriate for him/her by entering the related numbers in the formula or excel program", these interpretations were evaluated as "partially successful".

Internal reliability was checked by two academicians in mathematics education. Each academician was given a copy of the participants' responses and asked to write what each student did on the basis of "the variables used", "the mathematical work done generally", "the mathematical model posed", and "interpreting the model". Afterwards, by coming together, these results were compared. The differences were cleared up by reaching a consensus. In the results section, Turkish and English students' works have been indicated categorically and compared in terms of the categories above.

3. Results

3.1 Results Relating To The Diesel-Gasoline Problem

A. Results obtained from Turkish students

a. Mathematical work and understanding the problem

The 4 categories given in the paragraphs below were determined as a result of examining the solutions. These categories are given in order of being closer to the solution:

Four students found the difference of fuel consumption in 100 kilometers in urban and extra urban driving between diesel and gasoline cars and they interpreted that diesel cars were more economical. Eight students found the total cost (fuel cost and car price) considering a specific km for a specific or each car model and interpreted according to that. For example, they based their interpretations on driving 20 kilometers a day over five years or 10.000 urban kilometers and 1000 extra urban kilometers. Looking at the solutions, it is seen that the students determined the distances according to themselves. However, the important thing is to set a model showing the necessary combined urban and extra urban kilometers to recover the average price difference between diesel and gasoline cars. Therefore, these 12 students (32%) could not understand the problem at all.

15 students found the necessary urban and extra urban kilometers to recover the price difference between diesel and gasoline versions of a specific car model such as Citroen C3. It can be said that these students understood the problem better than the students above. However, considering the aim of the problem, these solutions are not enough due to the following reasons: (1) a specific car model was considered (2) the needed amount of kilometers were founded separately for only urban and only extra urban driving. Therefore, these solutions are not realistic as a driver does not drive either in urban or extra urban environments. In this situation, these 15 students (39%) could not understand the problem.

10 students tried to find the average needed urban and extra urban kilometers separately to recover the average price difference between diesel and gasoline cars. It can be said that these students understood the problem better than the students above as they produced a solution on the basis of average values considering all models. However, these solutions are not realistic as a driver does not drive either in urban or extra urban environments. Therefore, it can be said that these 10 students (26%) understood the problem partially.

One student set a two-variable formula by assigning the variable x for the amount of urban kilometers to be driven, and y for extra urban to recover the average price difference between diesel and gasoline cars. This formula is

$$30166 + 7{,}96x + 4{,}8y = 34666 + 5{,}31x + 3{,}61y$$

This student understood the problem but not very well as he did not interpret the formula.

b. Selecting the variables

26 students (68%) considered the total urban and extra urban kilometres as variables to recover the average price difference between diesel and gasoline cars. 12 (32%) students in the category 1 used no variable. Hence, 68% of the students became successful in selecting the variables.

c. Setting and interpreting the mathematical model

4 of the 38 students set a two-variable formula as a model. Two of them considered a specific model, one student took each model and one person considered average values (average fuel values and average price difference). As these formulas were for specific car models and only urban and only extra urban, these models and interpretations were evaluated as "partially successful". Another formula was average based. This formula

was evaluated as "successful" but had unimportant arithmetic errors. This student said: "the person can decide whether to buy a diesel car by writing the amount of kilometers to be driven in urban and extra urban environments in the place of x and y" as interpretation. This interpretation was evaluated as "partially successful".

In this situation, 34 students (90%) were evaluated as "unsuccessful", 3 students (8%) were evaluated as "partially successful" and one student (2%) was evaluated as "successful" in terms of setting a mathematical model. On the other hand, all (100%) of these four students who produced a model were evaluated as "partially successful" in terms of interpreting the two-variable model.

B. Results obtained from English students

a. Mathematical work and understanding the problem

Five (19%) students set a two-variable formula considering both urban and extra urban kilometers together and three of them interpreted in terms of these two variables drawing a graph. The solutions in this category can be summarized as "finding the amount of urban and extra urban kilometers to be driven to recover the average difference between the prices of diesel and gasoline cars". One student drew a graph showing the needed amount of kilometers to be driven to recover the average price difference between diesel and gasoline cars according to urban and extra urban driving rates. In this situation, four of these six students were considered to have "understood the problem very well", and two of them as "understood the problem".

Three students wrote a word model but did not interpret it. In the word model, the students expressed what to do in words. Two students (8%) composed an interactive Excel programme. In this program, the person enters the information required and sees the result relating to which car to buy. These five students were evaluated as "understood the problem". four students did arithmetic, and three students set a one-variable formula to find the needed average urban and extra urban kilometers separately to recover the average price difference between diesel and gasoline cars. In this case, these seven students understood the problem partially. Two students produced a one-variable formula on the basis of the necessary urban and extra urban kilometers separately. Therefore, these students did not understand the problem. Three students drew a graph showing the total cost (fuel cost and car price) by considering a specific km for a specific car model. One student produced a formula for the total cost of diesel cars. Two students did not make remarkable interpretations. Therefore, these 6 students did not understand the problem at all.

Selecting the variables. 23 students (88%) considered the urban and extra urban kilometers to recover the average price difference of diesel and gasoline cars as variables. Hence, while 88% of the students became successful in selecting the variables, 12% of the students became unsuccessful.

b. Setting a mathematical model and interpreting

Five (19%) students composed a two-variable linear formula such as:

$$14{,}98x + 7{,}56y = 4500$$

by considering both urban and extra urban kilometers together. 3 out of those 5 students drew graphs of the line equation and indicated the area above the line as the preferable part for buying a diesel car as interpretation. These three students' models and interpretations were evaluated as "successful". The other two students did not interpret their models.

One student drew a graph showing the kilometer amount needed to be driven to recover the average price difference between diesel and gasoline cars according to urban and extra urban driving rates. This students' model and interpretation were evaluated as "successful". Two students (8%) set an interactive Excel programme. In this program the person enters the information asked and sees the result relating to which car he/she should buy. These two students' models and interpretations were evaluated as "partially successful".

Finally, 18 students (69%) are "unsuccessful", two students (8%) are "partially successful" and six students (23%) are "successful" in terms of setting a mathematical model. On the other hand, four (50%) students are "successful", two students (25%) are "partially successful" and two (25%) students are unsuccessful in terms of interpreting the model.

3.2 Results Relating to The Problem of Population

A. Results obtained from Turkish students

The students tried to find a pattern by using the data, and then solved the problem either by setting a formula or by using ratios on the basis of the pattern that they found.

The mathematical work is divided categorically as follows:

(1) Linear solutions

Using all the data: Equation of Line (four students), The population of 2009 + average raise per year (12 students), Proportion over total population variation (four students)

Over the last 5 years: Changing average raise per year (three students), The population of 2009 + average raise per year (six students)

Other patterns (five students)

(2) Exponential Solutions (two students)

It can be seen in the students' mathematical models that five of them set a formula as a model and the others did arithmetic only. All the students who found a formula became "unsuccessful" as they could not obtain appropriate results. On the other hand, six (17%) students' predictions out of the 36 students' can be regarded as "partially successful" as they obtained approximate results and the other 30 students (83%) became unsuccessful.

B. Results obtained from English students

14 students firstly drew the graph of the data given using the Excel and determined the curve fitting the data best using the "trendline" in the menu and answered the question using the equation of this graph. 7 students' models out of these 14 students produced approximate results to the UK National Statistics.

Five students drew a graph of the data with the help of a program and printed this graph. Then, they made some drawings (extensions) on this curve by hand in order to find the answer. Only one student obtained appropriate results. Two students plotted a graph of the data given on a squared paper by hand and they tried to find the answer by extending this graph.

Looking at the students' mathematical work for the population problem in general, it seems that none of the students produced a formula by themselves. When the students' predictions are compared with the predictions of UK National Statistics, eight (38%) students were evaluated to be "partially successful" and 13 (62%) to be "unsuccessful".

3.3 Comparative Results

A. Comparative results related to the problem of diesel-gasoline

Turkish and English students' rates of understanding the problem are given in the Table 1.

Table 1: Turkish and English Students' Rates of Understanding the Problem

	Very Good	Good	Partially	Poor	Very Poor
Tr	0 (0%)	1 (3%)	10 (26%)	15 (40%)	12 (31%)
En	4 (15%)	7 (27%)	7 (27%)	2 (8%)	6 (23%)

Turkish and English students' rates of determining the variables are given in the Table 2.

Table 2: Turkish and English Students' Rates of Determining the Variable

	Successful	Unsuccessful
Tr	26 (68%)	12 (32%)
En	23 (88%)	3 (12%)

Turkish and English students' rates of setting and interpreting the mathematical model are given in the Table 3.

Table 3: Turkish and English Students' Rates of Setting and Interpreting the Model

	Successful	Partially Successful	Unsuccessful
Tr	1(2%), 0(0%)	3(8%), 1(25%)	34(90%), 3(75%)
En	6(23%), 4(50%)	2(8%), 2(25%)	18(69%), 2(25%)

On the other hand, when the results were examined in terms of accuracy of the whole mathematical modelling process for the diesel-gasoline problem; it was found that while four (15%) English students were successful; none of the Turkish students were successful.

The average points that the English and Turkish students obtained from the stages of mathematical modelling were compared with the Independent-Samples T-Test in SPSS and the results are given in the Table 4.

Table 4: The comparative t-test Results Relating to the Stages of Mathematical Modelling for the Diesel-Gasoline Problem

	$\overline{X}$		sd		df	t	p
	Tr	**En**	**Tr**	**En**			
Understanding the problem	2	3,04	,838	1,399	62	2,289	,000
Determining the variables	,68	,92	,471	,272	62	-2,330	,065
Setting the mathematical model	,11	,54	,311	,859	62	-2,855	,006
Interpreting the model	,25	1,25	,500	,886	9,637	-2,494	,033

In the Table 4, it is seen that there is a significant difference between Turkish and English students' average points of understanding, setting the mathematical model and interpreting the mathematical model. Hence, it can be said that English students' performances of understanding the problem, setting the mathematical model and interpreting the mathematical model are better than the Turkish students' performance significantly.

B. Comparative results related to the problem of population

Turkish and English students' rates of setting the mathematical model are given in Table 5.

Table 5: Turkish and English Students' Rates of Setting the Mathematical Model

	Successful	Partially Successful	Unsuccessful
Tr	0 (0%)	6 (17%)	30 (83%)
En	0 (0%)	8 (38%)	13 (62%)

By assigning the numbers 0, 1 and 2 to the categories of setting the mathematical model, the points that the English and Turkish students obtained were compared with Independent-Samples T-Test in SPSS and the results are given in Table 6.

Table 6: The Results of t-test Relating to the Scores of Setting the Mathematical Model

	N	$\overline{X}$	S	df	t	p
Tr	36	,17	,378	55	-1,835	,072
En	21	,38	,498			

It is seen that the difference between Turkish and English students' points of setting the mathematical model is not significant statistically ($p>.05$). Hence, it can be said that there is no significant difference between English and Turkish students' performances of setting a mathematical model for this problem.

In addition, as the ability of setting a mathematical modelling is common in both problems, Turkish and English students' ability of setting the mathematical model was compared together for the two problems. 38 Turkish and 26 English students answered the first problem, and 36 Turkish and 21 English students answered the second problem. Turkish and English students' rates of setting the mathematical model are given in Table 7.

Table 7: Turkish and English Students' Rates of Setting the Mathematical Model

	Successful	Partially successful	Unsuccessful	N
Tr	1 (1%)	9 (12%)	64 (87%)	74
En	6 (13%)	10 (21%)	31 (66%)	47

By assigning the numbers 0, 1 and 2 to the categories of setting the mathematical model, the points that the English and Turkish students obtained were compared with Independent-Samples T-Test in SPSS and the results are given in the Table 8.

Table 8: The results of t-test relating to the points of setting the mathematical model

	N	$\overline{X}$	sd	df	t	p
Tr	74	,15	,395	119	-3,155	,002
En	47	,47	,718			

In the Table 8, it is seen that English students' performance of setting the mathematical model is better than the Turkish students' significantly.

4. Discussion and Conclusions

In terms of the success rates relating the modelling stages and the accuracy of the whole mathematical modelling process, a great majority of the students could not be successful in the mathematical modelling process. On the other hand, in the population problem, while all of the Turkish students worked algebraically, 33% of the English students drew a graph, and 67% of them used Excel. That none of the English students struggled with algebra by using pencil and paper and none of the Turkish students attempted to use computer seems to be a remarkable result. Finally, none of the students became successful in terms of setting an appropriate mathematical model. Similar results were obtained by Christiansen (2001), Lingefjärd (2006), Türker, Sağlam & Umay (2010), Verschaffel, De Corte & Borghart (1997). Moreover, 17% of Turkish students and 38% of English students became partially successful. This difference was caused by Using computer software. Considering that as senior mathematics students, they have enough mathematical knowledge to be able to solve this problem, the fact that none of them was taught to solve this kind of problems can be seen as a major reason behind this failure as stated by Niss (2001) and Klymchuk & Zverkova (2001).

In the Diesel-Gasoline Problem, 90% of the Turkish students and 69% of the English students could not set a first-degree inequality in two-variables and became unsuccessful. 11% of the Turkish students and 19% of the English students were able to see the necessity of setting an equation in two variables like "$ax+by=c$" for the solution of the problem. However, none of the Turkish students and 12% of the English students were able to interpret this equation in two variables that they produced on the basis of the solution of the problem. As a general result, most of the students failed to deal with a real-life problem requiring the production of a mathematical model like "$ax+by=c$" and interpreting it by displaying the inequality of "$ax+by<c$" on the plane. Additionally,

firstly it is important to simplify the problem, and many students failed to do this. This difficulty is seen in several other studies (Blum & Ferri, 2009; Hodgson, 1997; Christiansen 2001; Haines, Crouch & Davis 2001). This simplifying requires using some algebraic expressions such as function and equation. In this case, the prospective mathematics teachers could not transfer the algebraic concepts such as function, equation and inequality that they learned in school to such a real-life problem. The results of a study carried out by Zeytun, Çetinkaya, Yıldırım, & Erbaş (2009) revealed that pre-service teachers faced difficulty in equation, interpreting graphs of functions, and graphing skills in modelling process. Erdoğan (2010) stated that students had difficulties using the concept of function significantly by solving modelling problems. Tanner and Jones (1995) observed that only knowledge is not enough to set a successful modelling, and those students also needed to know which knowledge must be used where, and at this point they had difficulties. In the study by Zeytun, Çetinkaya, Yıldırım & Erbaş (2009), it was seen that pre-service teachers had inadequate mathematical knowledge, especially in transition between proportion and equation, interpreting graphs of functions, and graphing skills.

One of the main problems in mathematics education is that students from elementary to university are taught mathematics in a procedural way, and they are not usually taught how to transfer their mathematical knowledge into real life problems. In this respect, their problem-solving performances become low. Therefore, as recommended by Crouch & Haines (2004), Kaiser (2007) and Lingefjärd (2006), if mathematical modelling activities are placed in mathematics lessons, it is no doubt that the students' modelling performances will be better.

The results of the current study are limited to the situation-content, students' experiences in modelling and their motivations. As indicated by Niss (2001), Busse (2001) and Galbraith & Stillman (2001), these factors could affect students' performances in the modelling process.

In conclusion, it seems that most of the students failed to deal with the given real-life problems. Although they had the required mathematical knowledge to solve the problems, they could not transfer their knowledge into the process of solution. In this case, as long as candidate mathematics teacher are not educated about mathematical modelling, it can be said that most of them will be unsuccessful. In addition, when Turkish and English prospective mathematics teachers' modelling performances are compared statistically, it was observed that English students' performances of understanding the problem, setting a mathematical model and interpreting the mathematical model are significantly better than the Turkish students' performances. In the results of TIMSS and PISA, it is seen that English students' mathematics performance is higher than Turkish students' (In PISA 2006, 2009, 2012, Turkish and English students' average points are 439 and 494 respectively. In TIMSS 2011, Turkey is 24^{th} and England is 9^{th}). These results show that English students' mathematical problem-solving performances are better than Turkish students' performance on the whole. As Niss (2003) stated, modelling is inseparably linked with applying problem solving strategies.

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