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TEACHER EDUCATORS' VIEWS OF "MODEL" CONCEPT AND THEIR MENTAL MODELS

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Abstract. *The aim of this study is to reveal teacher educators' views of model and also to determine their mental models about it. Phenomenographic research design has been carried out in this study. The sample of study consists of 14 teacher educators from education faculties of different universities in Turkey. Semi-structured interviews that consisted of 7 questions were used to collect data. Besides, sample was asked draw a concept map on "model" in the last interview question. Results have shown that teacher educators give similar responses including unqualified explanations to the interview questions related to the definition of model, characteristics of them, and the objectives of using models. It can also be asserted, that teacher educators do not have scientific understanding on the modeling process. The analyses of their responses to the interview questions and their concept maps have shown that most of the teacher educators in the sample have proximate or goal oriented mental models of the "model". Considering the results, it is suggested that teacher educators should not only follow the new theories, methods, or the applications in related literature theoretically, but also employ different theories, methods, or applications such as models and modeling in their courses.*

Key words: *model, modeling, teacher educators, mental model.*

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Introduction

Models play a significant role in the better development of real knowledge and teaching of sciences during the developmental process of science. Due to the abstract nature of sciences and to make the concepts accessible and comprehensible for students, models and modeling hold a significant position in science learning/teaching. The models which assist in visualizing complex ideas, processes and systems in learning/teaching science promote the emergence of questions that enables more intimacy with truth in order to formulize hypotheses that can be analyzed experimentally. In the production, spread and acceptance of scientific knowledge, models are necessary tools. While they are building a bridge between scientific theory and real life experiences, they also serve both as a simple demonstration of reality to obtain scientific data and conduct observation as a source of scientific explanations and estimations about a phenomenon. Functioning as visualizing abstract things, providing a base to explain experimental results and simplifying or describing a complex case, models are useful tools which enable individuals to foresee and explain the represented reality.

The use of models is quite widespread in science learning/teaching, so that a great number of model types we can be confronted in science. All these models present in the literature of science education have diversified classifications. For example, Harrison and Treagust (2000) have classified analogical models in their research. Their classification includes: *scale models*, *educational analogical models*, *symbolic models*, *mathematical models*, *theoretical models*, *maps, diagrams and tables*, *concept-process models*, *simulation*, *mental models and synthesis models*. A parallel classification has been done by Ünal and Ergin (2006) and they attempted to categorize the abovementioned models under two headings as *open models (simulation models)* and *latent (internal/mental) models*. Open models cover scale models, instructional analogical models, symbolic models, mathematical models, theoretical models, maps, diagrams and tables, concept-process models and simulations. While they are analyzing latent models under a different heading, synthesis models have not been mentioned. According to Örnek (2008a), the models in science education can be categorized under two headings: *mental models* and *conceptual models*. Conceptual models which are external demonstrations have been classified as mathematical, computer, physical (visual) and physics models. As seen in the classifications above, mental models always take place within the classifications in literature. They are internal representations having structural similarities in the real life events or processes. By visualizing concepts and processes in the mind, mental models are generated. Mental models are personal, internal and inconsistent with scientific explanations. They develop parallel to the acquisition of new information. It is specific and functional for the person who is the owner of the model. As stated by Norman (1983), mental models are mental presentations structured through interaction with reality and different mental models can be formed for one single system. Mental model is an internal process that is structurally similar to events or processes, and it plays the role of calculating personal thoughts for the estimation and explanation of physical phenomenon. In this study, teacher educators' views of "model" in terms of its definition, characteristics, types, objectives of use and modeling process were explored and discussed. By this means, teacher educators' mental models of the *"model"* concept were attend to explore and categorize.

Considering the fact that phenomenographic researches provide a chance to reveal qualitatively different ways in which people conceptualise, perceive, and understand various phenomena (Marton, 1981, 1986), the variations of teacher educators' views about model concept have been attempted to be determined in the present study. Although there have been many studies investigating students', prospective science teachers' or acting science teachers' views or knowledge about models and modeling (Aktan, 2013; Danusso, Testa, & Vicentini, 2010; Henze, Van Driel, & Verloop, 2007; Justi & Van Driel, 2005; Justi & Gilbert, 2002, 2003; Van Driel & Verloop, 1999), the number of studies investigating teacher educators' views about them is restricted. Driven from this point onwards, the aim of this study is to reveal teacher educators' views of "model" concept and also to determine their mental models about "model" concept.

Methodology of Research

General Background of Research

Phenomenography is one of the qualitative methodologies adapted for mapping the qualitatively different ways in which people experience, conceptualize, perceive, and understand various aspects of, and phenomena in, the world around them (Bowden et al., 1992; Marton, 1981, 1986). The methodology focuses on exploring the variation in the ways people experience a particular phenomenon (Yates, 2013). Phenomenographic research does not judge accuracy of people's ideas or how they are compatible with the facts. Its aim is not to find a singular essence, but to portray the experiences of peoples and to search variation and the architecture of this variation by different aspects that define the phenomena (Örnek, 2008b; Walker, 1998). In order to investigate teacher educators' views of "model" in terms of its definition, characteristics, types, objectives of use and modeling process and to explore and categorize their mental models of the *"model"* concept, phenomenography was selected as the research approach in this study. Phenomenograpy provides discovering this variation, to determine differences among their mental models of the *"model"* concept.

Sample

The sample of the study consists of 14 teacher educators from Karadeniz Technical University and Rize University. They are employed in the departments of Primary Science Education, Primary Mathematics Education and Secondary Science and Mathematics Education. Teacher educators in Department of Secondary Science and Mathematics Education have been studying on Biology, Physics, Chemistry and Mathematics Education. Moreover, the ones coded as M2 and B3 are the graduates from relevant departments in Faculty of Science and Letters, however they have been teaching at Faculty of Education. Demographic features of participant teacher educators are shown in Table 1.

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Table 1. Demographic characteristics of participant teacher educators.

Teacher educators	Study field
C1	Chemistry education
C2	Chemistry education
C3	Chemistry education
M1	Mathematics education
M2	Mathematics
M3	Mathematics education
P1	Physics education
P2	Physics education
P3	Physics education
B1	Biology education
B2	Biology education
B3	Biology
S1	Science education
S2	Science education
Total	14

Data Collection Tools

Data was collected by using semi-structured interviews which consisted of seven questions per interview. Semi-structured interviews allow for flexibility as answers can be further explored by means of probing, i.e. asking additional questions to clarify something or to expand upon something. Interview questions were designed in order to investigate teacher educators' views of the *"model"* concept in terms of its definition, characteristics, types, objectives of use and modeling process and to explore their mental models of the *"model"* concept. The main interview questions were as follows:

1. What does the concept of model mean to you?
2. What kind of characteristics do you believe must be available in a model?
3. Can you explain the modeling process?
4. What do you think is the objective of using models?
5. Which model types are you aware of?
6. Which models do you make use of in your courses?
7. Can you draw a concept map related to the *"model"* concept?

In the present study, teacher educators were intended to draw a concept map about "model" concept at the end of the interview process. Thus, required data was collected to reveal teacher educators' views of *"model"* concept and their mental model. Concept map is a learning-teaching tool that is frequently encountered in science education literature. This tool indicates how individuals understand different topics including various ideas or concepts. With concept maps, it is determined how the concepts in minds of people are related to each other. Therefore, mental models are thought to be closely related to concept maps. Williamson (1999) points out, that solo usage of concept map may be insufficient in exploring an individual's mental model. Therefore, the data about teacher educators' views of the *"model"* concept and their mental models were gathered by using their concept maps and also their responses and expressions to the interview questions. During the interviews, they were able to express their ideas and they were able to mention the relationships between some of their concepts more freely, although they might have forgotten to put these ideas or relationships in their concept maps.

Each semi-structured interview was approximately 30 minutes in duration and the interview was recorded by using a tape recorder. Subsequently, the interviews conducted with each teacher educators were transcript verbatim and each protocol was converted into the written documents.

Data Analysis

Content analysis was used in this study. Content analysis is a method of studying and analyzing communication in a systematic, objective, and quantitative manner for the purpose of measuring variables (Kerlinger, 1986). The answers, given by the teacher educators for each interview question, were separately analyzed; common and different views were encoded through forming themes. These themes were written out in the line with interview questions and the teacher educators' responses in different categories have been presented in this paper.

In the analysis of concept maps, the concept map related to *"model"* was firstly created by the researchers considering the earlier related studies (Vosniadou & Brewer, 1992; Harrison & Treagust, 2000; Greca & Moreira, 2001; Güneş, Gülçiçek & Bağcı, 2004). Then, it was reorganized and given its final form by regarding the suggestions of the two teacher educators having research on models and modeling. The final form of the concept map, created by the researchers, was shown in Figure 1 and employed as the criterion for the evaluation of participants' concept maps.

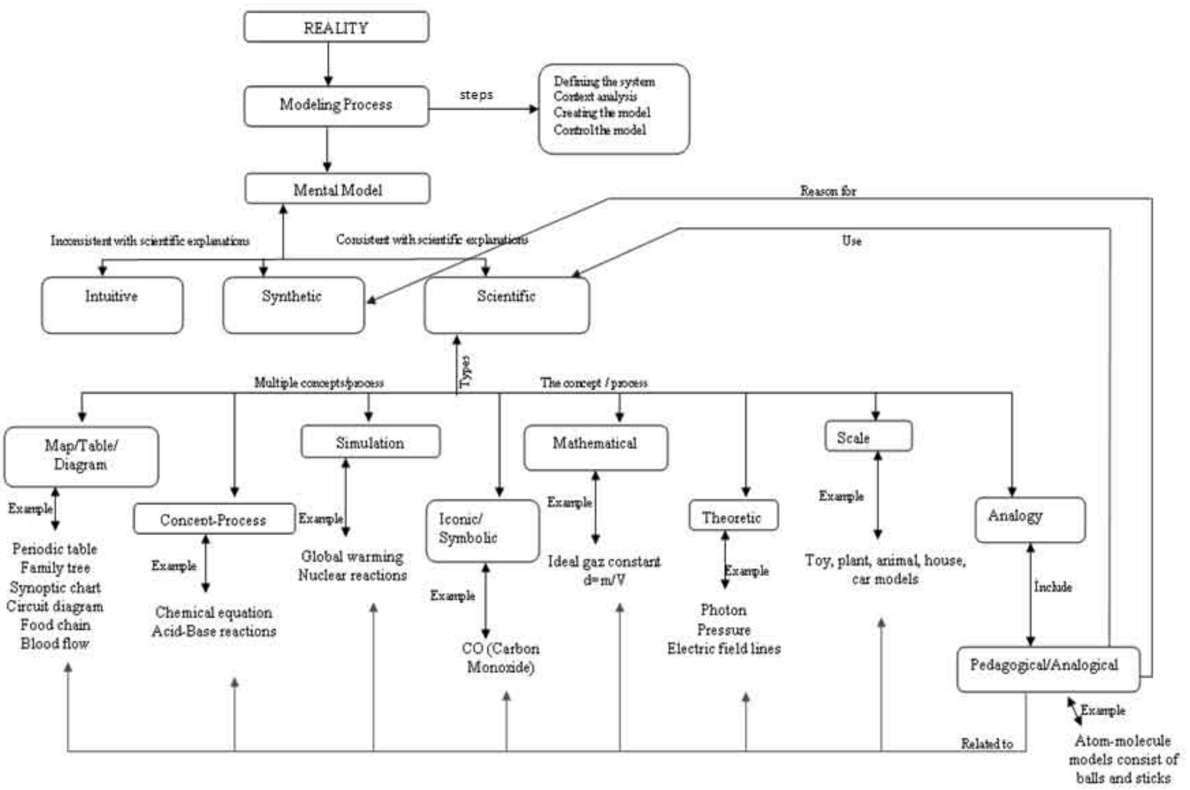

Figure 1 [1]: Concept Map of Model Drawn by Experts.

After examining the studies related to evaluation of concept maps (Novak and Gowin, 1984; Ünlü, İngeç and Taşar, 2006), 5 criteria were determined to evaluate both the concept map created by the researchers and those of participants. These criteria and their scoring key are shown in Table 2.

1 This concept map was created by considering the earlier related studies (Vosniadou & Brewer, 1992; Harrison & Treagust, 2000; Greca & Moreira, 2001; Güneş, Gülçiçek & Bağcı, 2004)

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Table 2. Criteria used for scoring the concept maps.

Elements of the concept map	Scoring
Concept	2 score
Proposition/connections	1 score
Hierarchies	5 score
Cross connections	10 score
Example	1 score

As shown in Table 2, in scoring the concept maps, the number of the correct concepts was multiplied with 2, that of the correct connections between the concepts with 1, that of the hierarchies with 5, that of the cross connections with 10 and that of the sample with 1. False elements of the concept maps (concepts, connections, examples, etc.) were scored 0. According to these evaluation criteria presented in Table 2, the concept map created by the researchers was scored. The possible maximum total score was 168. In the analyses process of concept maps, the participants' concept maps were scored by each researcher independently according to the aforementioned criteria. The consistency among the scores given by each researcher for the concept maps of each participant has been calculated. The consistency value was determined as 91%. Afterwards, the scores of participants' concept maps were calculated on the scale of 100. The categories for the classification of the concept maps were determined according to the score intervals out of 100. Categories for the concept maps and the score intervals out of 100 are shown in Table 3.

Table 3. Scoring intervals and categories of participants' concept maps.

Score intervals out of 100	Categories
100-90	Sound understanding
89-65	Understanding
64-33	Partially understanding
32-1	Poor understanding
0	No understanding

Besides the scores from the concept maps, their responses to the interview questions about the *definition of model,* the *general characteristics of the models, their objectives of use, their types* and *modeling process* were also taken into account when determining teacher educators' mental models about *"model"* concept. After examining all participant teacher educators' responses to interview questions and their concept maps, the categories used for classifying their mental models of *"model"* concept were determined and entitled with *"optimum mental model"*, *"proximate mental model"*, *"goal oriented mental model"* and *"inconsistent mental model"* by the researchers. The categories designed for classifying teacher educators' mental model of *"model"* concept and their descriptions are summarized in the Table 4.

Table 4. Categories used for determining participants' mental models of *"model"*.

Mental models	Characteristics (Participants …)
Optimum mental model	Give the definition of models, explain the modeling process (in 4 steps), their types, the characteristics of models, and the objectives of using models. Their concepts maps are classified within the category of sound understanding.
Proximate mental model	Give the definition of models, explain their types, the characteristics of models, and the objectives of using models, but have some deficiencies in their explanations. Explain the modeling process in 3 or 4 steps. Their concepts maps are classified within the category of understanding or partially understanding.
Goal oriented mental model	Give incomplete or inaccurate explanations about the definition of models, the modeling process, the characteristics of models, their types and the objectives of using models. Explain the modeling process simply in 2 steps. Their concepts maps are classified within the category of partially or poor understanding.

Mental models	Characteristics (Participants …)
Inconsistent mental model	Cannot give any explanations about the definition of models and the modeling process. Give inaccurate, incomplete or no explanations on the characteristics of models, their types and the objectives of using models. Their concepts maps are classified within the category of poor or no understanding.

As seen in Table 4, *the optimum mental model* is similar to those given in related literature (such as Oğuz, 2007; Gilbert, 2004). The modeling process of this model consists of four steps namely *context analysis, determining the form of the model, creating the model,* and *determining the validity of the model*. All types of models are listed. The characteristics of models are such that *"model does not reflect the reality represented one-to-one"*, *"model must reflect the reality represented to the greatest extent"*, *"model must be scientifically accepted"*, and *"model must be target-oriented"*. The objectives of using models are expressed in terms of both instructional and scientific aspects. Moreover, concept maps of this model are classified within the category of *sound understanding*.

The proximate mental model is in parallel to those given in related literature. The modeling process of this model consists of four steps as mentioned above or in three steps namely *description of the system to be modelled, creating the model,* and *re-examining of the system to control*. All types of models are not listed. The characteristics of models are such that *"model does not reflect the reality represented one-to-one"*, *"model must reflect the reality represented to the greatest extent"*, and *"model must be comprehensible"*. The objectives of using models are expressed in terms of both instructional aspects such as *enabling materialization of abstract and complex situations, assisting students to understand easier and better, enabling permanent and conceptual learning, visualization* and *simplification* and scientific aspects such as *obtaining information on reality* and *making scientific explanations on reality*. Besides, concept maps of this model are classified within the category of *understanding* or *partially understanding*.

In goal-oriented mental model, model is described as *"teaching materials used to explain facts"*. The modeling process of this model involves two steps consisting of *description of the system to be modeled* and *creation of its model*. All types of models are not listed. In this mental model are described only some theoretic structures of models when explaining the characteristics of models. The objectives of using models are expressed in terms of instructional aspects and give incomplete explanations such as *enabling materialization of abstract and complex situations, assisting students to understand easier and better, enabling permanent* and *conceptual learning*. In addition, concept maps of this model are classified within the category of *partially* or *poor understanding*.

In *inconsistent mental model*, any explanation about the definition of model, characteristics of models, their types and the objectives of using models are not given. If given explanations are inaccurate or incomplete, the explanations are evaluated in this mental model. And also, their concept maps are classified within the category of *poor* or *no understanding*.

Results of Research

In this part, data obtained from the interview questions have been presented under four main headings: (1) *Teacher Educators' Views of Models,* (2) *Teacher Educators' Views of Modeling,* (3) *Teacher Educators' Concept Maps on "Model"* and (4) *Teacher Educators' Mental Models of "Model"*.

(1) Teacher Educators' Views of Models

In this heading, the data related to teacher educators' views on models are presented regarding to their responses to the interview questions related to the definition of model, its characteristics, its types, and the objectives of using models.

Teacher Educators' Definitions of Model

In this sub-heading, the data related to teacher educators' definitions of model are presented regarding their responses to the first interview question. The participants' answers to the first interview question on the definition of model have been classified into some categories and summarized in Table 5. Some definitions of several teacher educators have been classified into more than one category for the first interview question related to definition of model.

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Table 5. Teacher educators' definitions of models.

Definitions	f	Teacher educators
Materializing abstract situations	11	P1, P2, P3, C2, C3, M1, M2, M3, B1, S1, S2
Teaching materials used to explain facts	7	B2, B3, P1, P3, C1, S2, M2
Simple representations of facts	6	M1, M2, M3, P3, C2, C3
Scientific models	1	S2
Mental schemas	1	S1

As shown in Table 5, most of the participants define model as *materializing abstract situations*. Some quotations from the interviews with the participants giving this definition are as follows; *"... simplifying a complex and abstract thing through some mental processes (C2)"* and *"Model is the expressions we use in defining or explaining an event, a situation or an object. It is rephrasing something. It is the manner of expressing something in a way more comprehensible to others (C3)".* These descriptions show that teacher educators define model by means of the objective of using models.

It is found out, that 7 participants have perceived *"model"* only as a *teaching material* when defining them in the interviews. The shared point in the expressions of these teacher educators is that they believe that anything used in teaching can be a model. Some quotations from the interviews with the teacher educators giving this definition are as follows; *"They are three- or two-dimensional physical materials that we can use in explaining a subject (B2)"* and *"...models are course materials to assist in teaching the subjects better (B3)".* These descriptions clearly show that some teacher educators perceive "*model*" as something used in teaching process, since they have generally used models in their courses such as ball-and-stick model for the structure of atom and human anatomy model for the structure of some organs of human body.

Six teacher educators in the sample of the study, on the other hand, define model as *simple presentations of facts*. This became evident from interview data when one of the teacher educators stated *"...there are some abstract concepts. For example; while introducing the concept of evolution, it is important to materialize the concepts and simplify them, so that children can understand better... (B1)"*.

As shown in Table 5, few teacher educators (S2 and S1) have particular definitions of models. One of them (S2) described models only as scientific models, while the other (S1) described models only as mental schemas. S2 stated that models were scientific models. And, he defined scientific models as "*data-based explanations and products which is made or presented by scientists*". This tendency of S1 and S2 who were defining models as scientific models only may be due to their area of interest and research. This situation can be understood from the explanations of S2;*"…I am interested in nature of science so I have a different viewpoint on this matter"*. Also, a quotation from the interview with S1 defining models as mental schemas is as follows; *"Models are mental schemas representing the reality or representing the combination of people's ideas and the reality".* Moreover, S1 gave the examples of atom models in the interviews. These explanations show that he/she might be attributing the origination of all models to the mental processes.

Teacher Educators' Views of the Characteristics of Models

In this sub-heading, the data related to teacher educators' views on the characteristics of models are presented regarding their responses to the second interview question. The teacher educators' responses to the second interview question on the general characteristics of a model are summarized in Table 6.

Table 6. Teacher educators' views on the characteristics of models.

	Characteristics of models (A model…)	f	Teacher educators
Theoretic structure	does not reflect the reality represented one-to-one	14	B1, B2, B3, P1, P2, P3, S1, S2, C1, C2, C3, M1, M2, M3
	must reflect the reality represented to the greatest extent	9	B1, B2, B3, P1, P2, C1, C2, C3, M1
	must be comprehensible	6	P2, P3, C1, M2, M3, S2
	must be free of scientific errors	4	B2, P2, P3, C3
	must be based on data	2	M3, S2
	must be scientifically accepted	2	M3, S2
Functional structure	must be open for change and improvement	9	B1, M2, M3, C1, C2, C3, P2, P3, S2
	can vary from person to person because each individual's perception of reality is different	7	B1, P3, C3, M2, M3, S1, S2
	must have an objective / must be target-oriented	4	C3, M1, M2, S1
	must be compatible with students' levels	4	B3, P1, M1, S1
	must attract attention or interest	3	B2, M1, M2
	must appeal to many senses	2	P1, M1
	must be economical	2	M1, M3
	must be simple	2	M2, S2
	must be evocative and familiar	1	M2

As seen in Table 6, the teacher educators have referred to both the theoretic structure and the functional structure of models. All participant teacher educators have stated that models cannot reflect all aspects of the reality represented. They agree that a model cannot reflect the reality represented one-to-one, because the reality has a more complex and detailed structure. A quotation from the interview with one of these teacher educators (C2) is as follows; *"…a model cannot reflect the reality exactly. There are some similar and different aspects between a model and the reality represented... Suppose that we are working in a company that builds sites. We should show the site and the apartments on a compact scaled model for clients. This model is designed for the clients in order to reflect its original form and make them imagine the final form of the site, but its size is not close to the reality…".*

Most of the sample (9 teacher educators) has claimed that a model is to reflect the reality represented as much as possible, although they have asserted that it cannot reflect the reality represented one-to-one. A quotation from the interview with one of these teacher educators (P2) is as follows; *"... a model must explain the reality in the best and accurate way. In other words, it must explain the reality with details and in a best realistic manner. It must be free from scientific errors. People must perceive and visualize it easily...".*

When answering the second interview question related to the characteristics of models, teacher educators have also mentioned the characteristics related to the functional structure of them. In this category, the most frequent explanation given by teacher educators is that structures of models are open for change and improvement. Teacher educators have also noted that the created model may change from person to person. A quotation from the interview with one of these teacher educators (M3) is as follows; *"...human beings always cannot reach absolute truths. We can create models only through our personal experiences. Our experiences may be sufficient at this time when we try to explain a fact or a reality, but may not be so in the future... Parallel to the changes in our experiences and technological developments, our observations can change and improve, so that our models can also change...".* These teacher educators' explanation that models can be changed in line with newly obtained data indicates that they do not see models as stable structures and are aware that they may change if required in the course of time.

Teachers Educators' Awareness and Usages of Model Types

In this sub-heading, the data related to teacher educators' awareness of the model types and their usage of them are presented regarding their responses to the fifth and sixth interview questions.

The teacher educators have been asked to state the types of models both they know about and they use in their classes. It has been found out, that some teacher educators fail to give the names of the types of models which they know about or they use in their classes, so they have tried to describe these types of models by giving examples or showing their in-class activities. During the analyses process, it has been assumed that teacher educators know about or use the types of models which they have attempted to explain by giving examples or presenting their in-class activities. The responses given by the teacher educators to the fifth and sixth interview question on the types of models are summarized in Table 8.

As shown in Table 8, when the participant teacher educators were asked for the types of models which they know about; *scale models* (13 teacher educators), *pedagogical analogical models* (11 teacher educators), *simulations* (10 teacher educators), *mathematical models* (9 teacher educators), *iconic and symbolic models* (8 teacher educators), *theoretic models* (8 teacher educators), *mental models* (8 teacher educators) and *concept-process models* (6 teacher educators) were mentioned in their explanations. On the other hand, when they were asked for the types of models which they used in their classes, they only mentioned about *scale models* (7 teacher educators), *pedagogical analogical models* (7 teacher educators), *simulations* (6 teacher educators), *mathematical models* (3 teacher educators), *iconic and symbolic models* (5 teacher educators), *theoretical models* (6 teacher educators), *concept-process models* (3 teacher educators), and *maps, diagrams, and tables* (2 teacher educators). Some quotations from the interviews with these teacher educators are as follows; *"...Suppose that we will teach the subjects of solar and lunar eclipses, a physical model can be designed and used in class. We have been teaching electric current using water flow analogy... We use the formulae of "F=m.a" as a mathematical model in the teaching of force… (P2)"* and *"...pedagogic analogical models, scale models, theoretic models, maps, diagrams, concept-process models, iconic-symbolic models... I'm giving a course on teaching methods for chemistry. For example, there is subject on teaching chemistry through simulations. In this course, after I explain the subject and give some examples about how simulations are used in chemistry teaching, I ask my students to design a learning environment in which chemistry concepts are taught using simulations and ask them to perform this lesson plan in our class. Prospective teachers employed simulations for teaching of different subjects and put their teaching plans into practice in our practice hours of the class. They (these simulations) are generally concept-process models... (C3)"*.

Table 8. Types of models that participants know about and use in their classes.

	Types of models which they know about		Types of models which they use in their classes	
Types of models	F	Teacher educators	f	Teacher educators
Scale model	13	B1, B2, B3, P1, P2, P3, C1, C2, C3, M1, M2, S1, S2	13	B1, B2, B3, P1, P2, P3, C1, C2, C3, M1, M2, S1, S2
Pedagogical/Analogical model	11	B1, B2, P1, P2, P3, C1, C2, C3, M1, M3, S2	7	B1, P1, P2, P3, C1, C2, M1
Simulation	10	B1, B2, P3, C1, C2, C3, M1, M2, M3, S2	6	B2, C1, C2, C3, M2, S2
Mathematical model	9	P2, P3, C1, C2, C3, M1, M2, M3, S2	3	P2, C3, M3
Iconic/Symbolic model	8	B2, B3, C1, C2, C3, M1, M3, S2	5	B2, C2, C3, M3, S2
Scientific/Theoretic model	8	P2, P3, C1, C2, C3, M3, S1, S2	6	P3, C2, C3, M3, S1, S2
Mental model	8	P2, P3, C1, C3, M2, M3, S1, S2	-	-
Concept-process models	6	B2, B3, P3, C2, C3, S2	3	B3, C3, S2
Maps, diagrams, and tables	5	B2, B3, P3, M3, S1	2	B3, S1

It has been determined, that some participants are actually familiar with certain types of models, although they have presented conflicting statements regarding the classification of them. Moreover, some teacher educators failed to give appropriate answers regarding what could be a model, their examples or the types of them, although they could provide the definition of model. It was determined that only half of the teacher educators who mentioned scale models, pedagogical analogical models and simulations in their explanations had been using these types of models in their courses. Furthermore, it is also determined that *theoretic models*, *mathematical models* and *iconic and symbolic models* were frequently mentioned by the teacher educators when they were asked for the types of models which they had known about.

Teacher Educators' Views of the Objectives of Using Models

In this sub-heading, the data related to the views of teacher educators' views on the objective of using models are presented regarding their responses to the fourth interview question. The views of the participant teacher educators on the objectives of using models are summarized in Table 9.

Table 9. Teacher educators' views on the objectives of using of models.

	The Views on the Objectives of Using Models	f	Teacher educators
Instructional objectives	Enabling materialization of abstract and complex situations	12	B1, B2, B3, P1, P3, C1, C2, M1, M2, M3, S1, S2
	Assisting students to understand easier and better	9	B1, B3, P1, P2, C1, C2, C3, M1, S2
	Enabling permanent and conceptual learning	7	B1, B3, P1, P2, P3, C3, S1
	Visualization	5	B3, P1, P3, C3, S2
	Simplification	5	B1, B2, B3, C2, M1
	Improving student success by making the student more active	2	P1, S1
	Enabling teachers to teach better	1	C3
Scientific objectives	Obtaining information on reality	6	C3,M1,M3,P2,P3,S1
	Making scientific explanations on reality	5	M2,M3,P3, C2, S2
	Providing support to the development of science	1	S2
The others	To use a common language, to communicate	1	C2
	To reveal what an individual thinks about reality	1	P3
	is used to produce solutions to the real life problems	1	M3
	is used to configure ideas in the desired manner	1	P3
	To make a person to be best known with his/her works on a discipline in the future.	1	S2

When the participant teacher educators' responses to the fourth interview question were analyzed, it has appeared that their views on the objectives of using models are classified into three main categories; *instructional*, *scientific* and *the others* (Table 9). It was determined that the teacher educators generally referred instructional purposes for the objectives of using models. Most of the participants (11 teacher educators) have stated that the objective of using models is to enable materialization of abstract situations. Half of the participants (7 teacher educators) have stated that the objective of using models is to assist student to understand easier and better, while half of them have noted that the objective of using models is to enable permanent and conceptual learning. Moreover, some participants (5 teacher educators) have reported the aim of using models is visualization, while some of them referred that the aim of using models is simplification. Some quotations from the interviews with these teacher educators are as follows; *"We use models to determine students' prior knowledge before teaching new subjects and to explain scientific knowledge and facts. We use models in order to materialize realities and facts for students. We employ models in our classes to improve conceptual understanding (P3)"* and *"We use models to materialize abstract situations ... to simplify complex processes, to teach students theoretical and abstract situations in a simple way and with simplified propositions ...to visualize the processes which cannot be observed (C2)".* As discussed in the earlier paragraphs related to the teacher educators' definitions of "model", the teacher educators' responses to the objectives of using models have also shown that most of them have considered models only as teaching materials.

Besides, 5 teacher educators stated that models can be used to obtain information on reality and 4 teacher educators reported that models can be used to make scientific explanations on reality. A quotation from the interview with one of these teacher educators is as follows; *"Since we can not obtain absolute facts, we create models that are closest to them. In order to reflect the absolute facts in the best possible way, we attempt to establish models closest to reality. It is a tool that enables us to explain the reality we don't know exactly... (M3)".* This finding that some teacher educators mention that models can be used to make scientific explanations on reality indicates that some teacher educators do not consider models only as teaching materials.

It is interesting that only one teacher educator (C2) has stated that the objective of using models is to communicate and to provide a common language for people. A quotation from the interview with C2 is as follows; *"especially symbolic and mathematical models are used to provide a common language for scientist and other people".* These statements demonstrate that C2 believes models are used in both scientific researches to make scientific explanations on reality and in providing a common language for people to communicate.

(2) Teacher Educators' Views on Modeling

In this heading, the data related to teacher educators' views on modelling and the modelling process are presented regarding their responses to the third interview question. Teacher educators' responses to the third interview question investigating their perceptions on modeling process have demonstrated that they have different explanations about modeling process. Teacher educators' views and explanations about the modeling process have been presented in Table 7.

Table 7. Teacher educators' views on modeling and modeling process.

		f	Teacher educators
Definition of Modeling	Model formation process	4	C2, M1, M2, S2
	The process of expressing the reality in different ways	3	C3, M3, P2
	The act or process of materializing the thoughts	1	P3
	Experimental process skills	1	S1
	None	5	P1, B1, B2, B3, C1
The steps of modeling process	2-steps model	5	P1, B1, B2, B3, C1
	3-steps model	6	P2, P3, M1, M2, M3, C2
	4-steps model	3	S1, S2, C3

As given in Table 7, the participant teacher educators' views on modeling process can be summarized in two categories; *"definition of modeling"* and "*the steps of modeling process*". When defining the modeling process, four teacher educators described modeling as the process of expressing the reality in different ways. A quotation from the interview with one of these teacher educators (C3) is as follows; *"Modelling is the process of expressing an existing situation, reality, event or an object in different ways...".* The definition of modelling as the process of expressing reality in different ways indicates that these teacher educators are aware of the possibility of creating different models for a single reality. As seen in Table 7, P1, C1, B1, B2 and B3 coded teacher educators did not present a clear definition of modelling.

As regards to the steps of the modeling process, 7 teacher educators refer to a 2-step process, 4 teacher educators refer to a 3-step process and 3 teacher educators refer to a 4-step process. In related literature, the modeling process is referred as the process consisting of three or four steps. It has been found out, those teacher educators who describe modeling as a 2-step process cannot make enough explanations about the modeling process. These teacher educators described the modeling process simply through the stages of "*defining the fact to be modeled*" and "*creating the model*". A quotation from the interview with one of these teacher educators (P1) is as follows: *"Model is the concrete form of reality. Modeling is that process, namely, the process of transforming the reality in a concrete form. Firstly, the teacher determines the concepts which his/her student has difficulty in understanding... Thinking the properties of these scientific concepts, required equipments and materials are provided, and then the model is created. In fact, I don't remember the details exactly what can take place in the stages of this process… ".* The teacher educators who describe modeling as a 3-step process have defined these steps as; *"defining the concept to be modeled"*, *"deciding the type of model"* and *"creating the model"*. A quotation from the interview with one of these teacher educators (M3) is as follows: *"...First of all, the reality to be modeled should be examined. After that, related literature should be examined, and the missing and incomplete aspects of the current models in the literature should be determined. By considering the collected data and by organizing them, the model should be created…".* When we examine their explanations for modeling process, it is remarkable that the teacher educators suggesting 3-step model for the process of modeling have not considered testing the validity of the created model as a step in the modeling process. The teacher educators who describe modeling as a 4-step process have defined these steps as; *"defining* *the concept to be modeled"*, *"deciding the type of model"*, *"creating the model"* and *"testing the validity of the model"*. A quotation from the interview with one of these teacher educators (C3) is as follows: *"... We shall think about a scientist who is trying to explain the structure of an atom. After he/she decide what kind of model would be appropriate the structure of atom, he/she begin to create the model which can reflect the structure of atom in the best way taking his/her experiences and the data gathered into consideration. After designing the model, he/she re-examine the model considering the similarities and differences between the model and the reality represented.... (C3)".*

(3) Teacher Educators' Concept Maps on "Model"

In this heading, the data related to the teacher educators' concept maps on "models" are presented regarding their responses to the seventh interview question. The results of the analyses of the teacher educators' concept maps on "models" are presented in Table 10.

As seen in Table 10, some teacher educators (C1, P1, B2, B3) could not draw an inclusive concept map related to "model". This case can be attributed to the fact that they were not experienced in preparation of a concept map, and this may be due to the fact that they don't use concept maps during their teaching classes.

Table 10. Information about teacher educators draws concept maps.

Teacher Educators \ Elements of concept maps	Concepts	Proposition/ connections	Hierarchies	Cross connections	Example	Total score	Scores out of 100	Categories of concept maps
C1	10*2	12*1	2*5	-	2*1	44	26	Poor Understanding
C2	22*2	22*1	2*5	4*10	5*1	121	72	Understanding
C3	24*2	24*1	2*5	1*10	-	92	55	Partially Under-standing
M1	12*2	17*1	2*5	-	7*1	58	35	Partially Under-standing
M2	13*2	16*1	2*5	-	4*1	56	35	Partially understand-ing
M3	13*2	13*1	2*5	4*10	-	89	53	Partially Under-standing
P1	12*2	12*1	2*5	-	-	46	27	Poor Understanding
P2	12*2	12*1	2*5	4*10	2*1	88	52	Partially Under-standing
P3	11*2	15*1	2*5	3*10	2*1	79	47	Partially Under-standing
B1	11*2	11*1	1*5	2*10	-	58	35	Partially Under-standing
B2	11*2	10*1	1*5	-	-	37	22	Poor Understanding
B3	10*2	10*1	1*5	-	-	35	21	Poor understanding
S1	21*2	21*1	1*5	3*10	2*1	100	60	Partially Under-standing
S2	12*2	10*1	2*5	1*10	5*1	59	35	Partially Under-standing
The Concept Map by Researchers	16*2	23*1	3*5	9*10	8*1	168	100	-

As indicated in Table 10, a good number of teacher educators provided valid concepts and correct relation-

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ships in their concept maps related to models, but their concept maps generally consist of 1 or 2 hierarchies. It was determined that C2, C3, M3, P2, P3, B1, S1 and S2 teacher educators have established cross connections among the concepts in their concept maps. It shows the fact that they know and express clearly the relations among the concepts related to models. Moreover, C3, M3, P1, B1, B2 and B3 teacher educators gave examples of related concepts in their concept maps whereas the others did not present any examples. Besides, the concept maps of C1, P1, B2 and B3 were classified into *poor understanding,* those of C3, M1, M2, M3, P2, P3, B1, S1 and S2 were classified into *partially understanding* and C2 was classified into *understanding* category, when teacher educators' concept map scores were analyzed. Four concept maps having different scores and created by the participants are presented as examples in Figure 2.

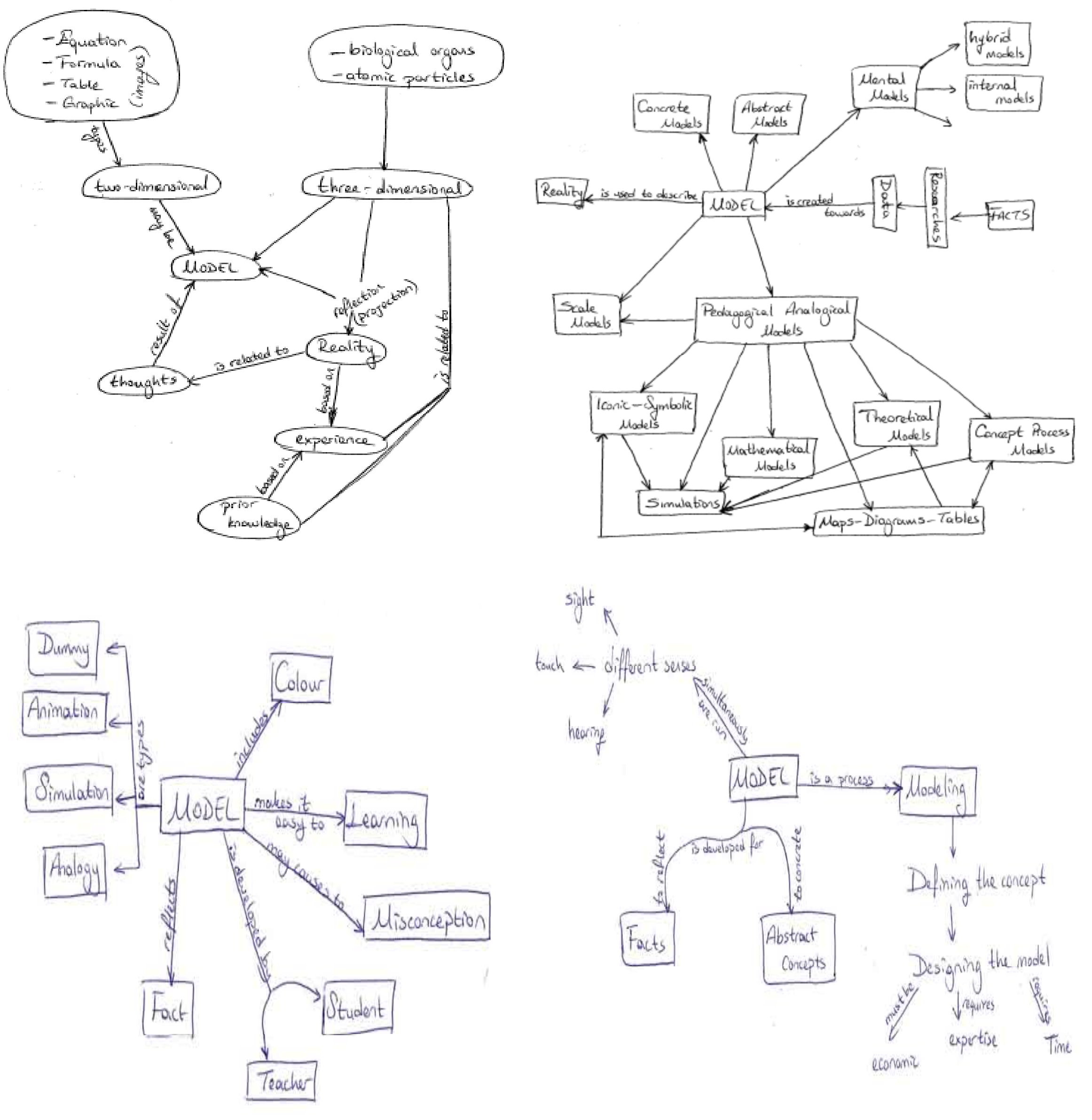

Figure 2[2]: Some concept maps on *"model"* created by participant teacher educators.

2 The concept maps created by academicians were translated verbatim from Turkish to English by the researchers.

(4) Teacher Educators' Mental Models of "Model"

In this heading, the data related to teacher educators' mental models of "model" are presented regarding to their responses through the interviews. In the determination of teacher educators' mental models of *"model"*, their views about the definition of model, the characteristics of models, the objectives of models, types of models, and the modeling process were taken into account. Moreover, their concept map scores were also considered as another criterion to determine their mental models of *"model"*. The categories designed for classifying teacher educators' mental model of *"model"* concept and their descriptions was presented in the analyses part of the paper. After the analyses of teacher educators' responses to the interviews questions and their concept maps considering this categories, their mental models of *"model"* was determined and presented in Table 11.

Table 11. Teacher educators' mental models of *"model"*.

Teacher educators	Model definition	Characteristics	Modeling process**	Model types	Objectives	Concept map scores	Mental model
C1	-	⅄	-	⅄	⅄	Poor Understanding	Goal oriented
C2	+	⅄	⅄	⅄	⅄	Understanding	Proximate
C3	+	⅄	⅄	+	⅄	Partially Understanding	Proximate
M1	+	⅄	⅄	⅄	⅄	Partially Understanding	Proximate
M2	+	⅄	⅄	⅄	⅄	Partially understanding	Proximate
M3	+	⅄	⅄	⅄	⅄	Partially Understanding	Proximate
P1	⅄	⅄	-	⅄	⅄	Poor Understanding	Goal oriented
P2	⅄	⅄	⅄	⅄	⅄	Partially Understanding	Proximate
P3	+	⅄	⅄	⅄	⅄	Partially Understanding	Proximate
B1	⅄	⅄	-	⅄	⅄	Partially Understanding	Goal oriented
B2	-	⅄	-	⅄	⅄	Poor Understanding	Goal oriented
B3	-	⅄	-	⅄	⅄	Poor Understanding	Goal oriented
S1	⅄	⅄	⅄	+	⅄	Partially Understanding	Proximate
S2	⅄	⅄	+	+	⅄	Partially Understanding	Proximate

** '-'; Response including irrelevant, unclear or no information, '+'; Responses including all components of the validated response, '⅄'; Responses including some of the components of validated response, but not all the components*

*** The modeling process is evaluated considering both aspects; definition of modeling and the steps of modeling process. For instance, if an teacher educator cannot give the definition of modeling and he/she explained the modeling process in 2 steps as well, he/she is marked as '-'.*

As seen in Table 11, none of the teacher educators possesses *optimum* and *inconsistent mental model* of "model". While C2, C3, M1, M2, M3, P2, P3, S1 and S2 coded teacher educators have *proximate mental model*, C1, P1, B1, B2 and B3 coded teacher educators have *goal oriented mental model*.

Teacher educators, who gave correct definitions of model, explained the modeling processes (in 3 or 4 steps), listed the types of models, explained their characteristics and the objectives of using models; but had some deficiencies in their explanations/statements were classified under the category of *proximate mental model*. When defining the *"model"* concept, C2 coded teacher educators' explanations in this category were as follows; *"... simplifying ... simplifying a complex and abstract thing through some mental processes. For instance, it is difficult for a student to visualize an atom in his/her mind. The steps which are employed for materializing a complex case, theory or a concept are the steps of modeling. These steps were named as modeling. The product revealed as the result of modeling process is called as model"*. P2 coded teacher educator also explained the model as *"the thing which explain the*

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reality. It shows the relationships between a real situation and the model which reflect to it. It enables us to understand how certain events in the world happen. It is used to materialize abstract situations…". As seen from the quotations, the teacher educators in this category generally defined *model* concept as *"materializing abstract situations"* and *"simple representations of facts"* (see Table 5). Also, teacher educators having *proximate mental model* explained the modeling process in 3 or 4 steps in parallel with those in related literature (see Table 7). C2 coded teacher educators' explanation about modeling process were as follows; "*The steps which are employed for materializing a complex case, theory or a concept are the steps of modeling. These steps were named as modeling. First of all, you should describe the reality to be modelled within all aspects. Then, you should gather information about it and the earlier models created by the others. Regarding the missing points or strengths of earlier models, you can create a model which explains the reality better than the earlier…".* The teacher educators in this category also addressed the theoretic and functional structure of models as characteristics of them. "*A model does not reflect the reality represented one-to-one* (P2,P3,S1,S2,C2,C3,M1,M2,M3), *reflect the reality represented to the greatest extent* (P2,C2,C3,M1), *be comprehensible* (P2,P3,M2,M3,S2) and *be free of scientific errors* (P2,P3,C3)" were related to the theoretic structure of models, while "*a model must be open for change and improvement* (M2,M3,C2,C3,P2,P3,S2), *be target-oriented* (C3,M1,M2,S1), *be compatible with students' levels* (M1,S1) and *may vary from person to person because each individual's perception of reality is different* (P3,C3,M2,M3,S1,S2)" were related to the functional structure of them (see Table 6). They could explain the relationship between a model and the reality represented. For instance, a quotation from the explanations of P2 was as follows; *"… The facts cannot be clearly represented on models. Models are constructions we create in our mind in order to explain how an event or situation happens. However, the truth is that situations or events in real world have fine details that we cannot see..."* (see Table 6). With regards to the types of models, all teacher educators having this mental model could list the most types of models beyond *scale* (M3), *iconic/symbolic* (M2,P2,P3,S1) and *mental* (M1,C2) models (see Table 8). A quotation from P2 explanations about the model types was as follows; *"... Suppose that we will teach the subjects of solar and lunar eclipses, a physical model can be designed and used in class. We have been teaching electric current using water flow analogy... We use the formulae of "F=m.a" as a mathematical model in the teaching of force…".* Teacher educators in this category could not presented detailed information about the objectives of using models. They generally preferred to mention about and emphasize on the instructional objectives of using models such as *enabling materialization of abstract situations* (P3,C2,M1,M2,M3,S1,S2), *making students understand easier and better* (S2,P2,C2,C3,M1) and *achieving conceptual and permanent learning* (P2,P3,C3,S1) rather than the others such as *obtaining information on reality (*C3,M3,P2,P3,S1*)*, *making scientific explanations on reality (*M3,P3,S2,C2*)*, and *communicating* (C2) (see Table 9). A quotation from P2 explanations was as follows; *"… We use them to help students understand the events or the relationships among the events in an easier, realistic and perfect way. Using models in science classes provide more permanent learning. This is for teaching or learning. Of course models are also used for general aims. For example, scientist create models to obtain more information about reality being investigated...".*

Considering the concept maps drawn by the teacher educators who had *proximate* mental model, it was found that they generally drew concept maps within the category of *partially understanding* (C3,M3,P2,P3,S1,S2) beyond C2 whose concept map was in the category of *understanding* (see Table 11). For example, P3 drew a concept map including some types of models such as iconic/symbolic, maps, diagrams, and tables. He drew a link between "reality" and "model" concepts and wrote the correct relationship between them in his concept map. He put the instructional objectives of using models into his concept map. Also, his concept map includes the properties of a person who is to create a model such as "experience" and "scientific process skills" (see Figure 2). C3 also drew a concept map including the types of models such as iconic/symbolic, mathematical, simulation, scale, scientific/theoretic models, diagrams, tables and mental models. Similarly, he showed a link between "model" and "reality" concepts and wrote the correct relationship between them in his concept map (see Figure 2).

As seen in Table 11, it was determined that C1, P1, B1, B2 and B3 coded teacher educators had *goal oriented mental model of* "model". Teacher educators, who could not provide an exact definition of "model", could give incomplete explanations on the characteristics of models, their types, the modeling process and the objectives of using models were classified under the category of *goal oriented* mental model. It was observed that the teacher educators in this group described the model only as *materializing abstract situations* (P1, B1) or/and *teaching materials used to explain facts* (B2, B3, P1, C1) (see Table 5). B2 coded teacher educator described the model as a teaching material; "*Models are three dimensional or two dimensional physical materials that we can use to explain a subject...*" (see Table 5). They could not express the modeling process exactly, and could not give a clear definition for the modeling process. Nevertheless, they mentioned about two steps for modeling process including *the definition of* *the fact to be modeled* and *the creation of the model* (see Table 7). When responding to the third interview question related to the modeling process, B1 explained 2-steps for modeling process clearly and he described the abilities of a person who would create a model. A quotation from his explanation was as follows; *"...the person who will create a model must be expert in the particular subject to be modeled. To illustrate a fact, different people can use different models. It is not a rule that everyone has the same perspective on a matter..."*. With regards to the types of models, P1 and B1 could not list or mention about *concept-process models maps, diagrams, and tables, mathematical models, iconic/symbolic models, scientific/theoretic models and mental models* (see Table 8). A quotation from the interview with B1 is as follows; *"...for example while teaching the DNA, I make use of the coat zipper of the students. In this example, the zipper is my model. Each chain in the zipper represents a chain in DNA... In the course of Environmental Science, I use PowerPoint presentations. I rarely use animations and simulations, because I don't know how to prepare them.* Teacher educators having this mental model also pointed out some characteristics of models. These were; "*model does not reflect the reality represented one-to-one*", "models *must reflect the reality represented to the greatest extent*, "models *can vary from person to person because each individual's perception of reality is different"* and "models *must be compatible with students' levels"* (see Table 6). The teacher educators having goal oriented mental model explained the objectives of using models only in regards to instruction/teaching. They listed the objectives of using models such as *enabling materialization of abstract situations* (C1, P1, B1, B2, B3) and *achieving conceptual and permanent learning* (B1,B3,P1), and *visualization* (see Table 9). B1 mentioned the instructional objectives of using models but also he claimed that models were used for simplification of facts as well. A quotation from his explanations was as follows; *"...there are some abstract concepts... For example, while introducing the concept of evolution it is important to materialize these concepts and simplify them so that the child can comprehend better...."* (see Table 9).

Considering the concept maps drawn by the teacher educators who had *goal oriented mental model*, it was seen that most of them drew concept maps within the category of *poor* or *no understanding* (C1, P1, B2, B3) (see Table 11). For example, B2 drew a concept map including only a few types of models such as animations, simulations, analogies, and scale models. He did not include *mathematical*, *scientific/theoretic model* and *mental model* in his concept map. He drew a link between "*reality*" and "*model*" concepts and wrote the correct relationship between them in his concept map. He put only the instructional objectives of using models into his concept map. Also, he did not include *modeling process* and *the characteristics of models* in his concept map (see Figure 2). Besides, P1 coded teacher educator put some characteristics of models into his concept map (to be economic). He indicated that models appeal to the senses such as seeing, hearing, and touching. He indicated that the objective of using or creating models was to materialize abstract concepts and to reflect complicated facts in a more apprehensible way in his concept map. Also, his concept map includes the properties of a person who will create a model (to be expert, to need time). However, he did not include the types of models in his concept map. He did not draw a link between "reality" and "model" concepts and did not write the relationship between them in his concept map (see Figure 2).

Discussion

Models are simplified representations of a system and they concentrate on the specific aspects of it (Oğuz, 2007). Moreover, Gilbert (2004) expresses the models as simplification of the observed real descriptions of the applied abstract theories to be developed for the specific purposes. As seen in Table 5, most of the participants define model as *materializing abstract situations*. This situation shows that teacher educators define models by means of the objective of using models. According to Norman (1983) and Harrison (2001), a model is the representation or modeling of our experiences and is directly related to target systems or phenomena. Also, 7 participants have defined model only as a *teaching material*. These definitions clearly show that some teacher educators perceive "*model*" as something used in a teaching process, since they have generally used models in their courses such as ball-and-stick model for the structure of atom and human anatomy model for the structure of some organs of a human body. Similar findings were reported earlier by Farmer (1994), and Smit and Finegold (1995). Smit and Finegold (1995) reported that prospective teachers considered models only as the scale models representing the reality (human body, bugs, skeleton etc.). The definition of "model" as a teaching material used in objectifying events or theories in science, given by the participant teacher educators shows parallelism with that of prospective teachers as reported in the study of Smit and Finegold (1995). This case may be originated from that prospective teachers' views about models must have been gained from their experiences in their undergraduate courses, and affected from their teachers' (teacher educators') views. 6 participants, on the other hand, defined models as *simple* *presentations of facts*. Their definitions are in accordance with those in related studies (Gilbert, Boulter and Elmer, 2000; Henze, van Driel and Verloop, 2008). Gilbert, Boulter and Elmer (2000) describe models as the representations of a thought, an object, a situation, a process or a system. Henze, van Driel and Verloop (2008) define models as simplified representations of facts in order to explain and visualize different phenomena. In their research, Van Driel and Verloop (1999) investigated experienced science teachers' knowledge on models and modeling. They have reported that most of the science teachers gave the same definition such as, that a model is a simplified representation of a fact. Berber and Güzel (2009) have revealed that most prospective teachers perceive models as the representations of facts but not the exact copies of them. Moreover, S1 described models only as mental schemas. His explanation shows that he might be attributing the origination of all models to the mental processes. Güneş et al. (2004) in their study have reported that most teacher educators are aware that new arrangements are taking place in the mind in respect to the facts represented by models, and this enables people to evaluate the facts from different perspectives.

A model has a structure that enables people to pre-estimate and explain the reality represented. Due to complex structure of the systems in real life, a model is mostly related to a small part of the reality represented. Models reflect only a few properties related to the target objects, ideas, or systems. A model can also be considered and used as a research tool in order to obtain information about a target that cannot be observed or measured directly. Models can change in the light of new information. These are the most common characteristics of models. The results of the study show that participants agree with the failure of model to represent the reality one-to-one shows us that they are all aware that events, objects, situations, theories etc. in real life are more complex and have fine details unlike the simpler structure of models. Güneş et al. (2004) have reported that teacher educators are aware that there might be unshared features between a model and the reality represented by it, although there may also be common features as well. Berber and Güzel (2009) have also revealed that prospective teachers consider models not as the exact copies of reality but as only representations of them. Contrary to these studies, Farmer (1994) asserted that teachers failed to give clear explanations on the difference between a model and the reality represented. Also, Barnea et al. (1995) stated that pre-service and in-service teachers failed to clearly explain the difference between models describing a process or phenomenon and mental thoughts. Teacher educators stated that model must be similar with reality represented as much as possible. Most participants in the sample claimed that a model is to reflect the reality represented as much as possible, although they have asserted that it cannot reflect the reality represented one-to-one. This result shows parallelism with Justi and Gilbert's (2003) study. They found out that teachers believe that the models must be similar with the reality represented as much as possible.

In parallel with related literature, participants of the study declared that the structures of models are open for change and improvement. This result indicates that they do not see models as stable structures and are aware that they may change if required in the course of time. This result shows parallelism with the studies of Grosslight et al. (1991), Güneş et al. (2004), and Berber and Güzel (2009), but differs from Chittleborough et al. (2005). Grosslight et al. (1991) have reported that students think that a model can change when it is disproved or when the fact represented is changed. Güneş et al. (2004) and Berber and Güzel (2009) have reported that more than half of the prospective teachers think that scientific models may change in the future. On the other hand, Chittleborough et al. (2005) have claimed that prospective teachers do not have sound understanding about non-stable structure of models because they have found out that half of them believe scientific models will not change in future. Justi and Gilbert (2003) probed teachers' views about the models and they reported that almost half of the primary school teachers and biology teachers believed that scientific models are stable structures, while physics and chemistry teachers believed that they can change in the course of time.

In related literature, types of models are presented as; *scale models, pedagogical analogical models, simulations, mathematical models, iconic and symbolic models, theoretical models, maps, diagrams and tables, concept-process models, scientific models, mental models* and *synthetic models* (Harrison and Treagust, 2000). It is found that some of the participants did not mention the types of models which they knew when they were asked for the types of models which they used in their classes. The inconsistency between model types stated by the teacher educators and those used by them in their classes can be explained with respect to their course context and their disciplines, because models types which can be employed in different disciplines can differ from each other. Since they did not know exactly the nature of these types of models, they did not mention the names of the model types when they were asked, even though they had employed these types of models in their lessons. This may be another reason for the inconsistency between the model types known by the teacher educators and those used by them in their classes. All in all, it can be deduced that some teacher educators have failed to give exact definitions and the examples of the types of models. This finding is parallel to the works of Grosslight et al., (1991), Güneş et al., (2004), and Berber and Güzel (2009). Similar to our study, Güneş et al. (2004) reported that although almost half of the teacher educators defined tables, formulas, chemical symbols and diagrams as the examples of models, most of them also defined mock-ups and toys as models. Furthermore, it was determined that the examples of models given by teacher educators were restricted with scale models, pedagogical analogical models, mathematical models, theoretic models and maps, diagrams, and tables. Berber and Güzel (2009) reported that a majority of prospective teachers were not aware that pedagogical analogical models, simulations, mathematical equations, theoretic models, iconic and symbolic models were some types of models. Grosslight et al. (1991) claimed that most students mentioned the concrete models of physical objects (planes, buildings, etc.), mathematical models, theoretical models, and two-dimensional-models such as drawings, diagrams, maps and simulations when they were asked to give the examples of models.

The objectives of using models have been referred as making a system apparent or visible (Gilbert, 2004); documenting a system (Gilbert et al., 2000); simplifying a complex system (Norman, 1983; Ingham and Gilbert 1991; Glynn and Duit 1995; Harrison, 2001); describing a system and its elements, its structure, and the actions and the relations between the elements in it (Harrison, 2001; Treagust, 2002); assisting the construction of ideas and knowledge, acting as a tool for communication amongst people (Özcan, 2005) and making scientific explanations and estimations on a phenomena (Gilbert et al., 2000; Harrison, 2001). The results showed that most of the participants referred instructional purposes for the objectives of using models. Moreover, some of them referred "assisting students to understand easier and better", "enabling permanent and conceptual learning" and "visualization" as the objectives of using models. These statements indicate that most participants have considered models only as teaching materials, as discussed in the earlier paragraphs related to the teacher educators' definitions of "model". In parallel with this perception, they have generally declared that models are used for instructional purposes. However, there are different objectives of using models such as defining a system, establishing communication and making explanation etc. (Gilbert, et al., 2000; Harrison, 2001; Özcan, 2005; Treagust, 2002). However, some of the teacher educators mentioned, that models could be used to make scientific explanations on reality. This result indicates that some teacher educators do not consider models only as teaching materials. Contrary to this result, Berber and Güzel (2009) stated, that most prospective teachers gave no heeds to the instructional role of the models, yet they reported that models were effective in learning scientific ideas and concepts. In the study, only C2 mentioned that models were used in both making scientific explanations on reality and providing a common language for people to communicate. Models play a crucial role in the communication among scientists (Van Driel and Verloop, 1999). Why only one participant has mentioned this objective of using models that the others may neglect the fact that models contribute to the development of science.

Modeling is a complex process covering multi-stage procedures, in which each detail takes place in what way and where is determined (Güneş et al., 2004), to make an unknown target clear and understandable through using current resources and information (Harrison, 2001; Treagust, 2002). All participants, except five presented a clear definition of modelling process. Their definitions of modeling as the process of expressing reality in different ways indicate that these teacher educators are aware of the possibility of creating different models for a single reality. This finding is parallel with the result of the studies by Güneş et al., (2004), Chittleborough et al., (2005), and Berber and Güzel (2009). Güneş et al. (2004) have reported that teacher educators agree that various models can be employed when describing the features of a scientific event. Berber and Güzel (2009) have also noted that almost all prospective teachers agree that a number of models can be created to explain one single fact.

In relevant literature, modeling is referred as a three- and four-step process. Three-step modeling process consists of *defining the system, creating the model*, and *returning back to the system to control*; while four-step process consists of *context analysis, determining the form of the model*, *creating the model*, and *determining the validity of the model* (Boulter and Buckley, 2000). Justi and Gilbert (2003) conducted a study investigating the role of modeling in teaching and learning science, and they suggested a five-step model for the modeling process by examining the relevant literature. The steps of this model are; *"learning the model", "learning to use the model", "learning how to examine the model", "learning to restructure the model"* and *"learning to restructure the model if it is rejected".* In our study, teacher educators generally referred to 2 or 3 step process. Moreover, few of them referred to four-step modeling process in harmony with the steps of the modeling process defined by Boulter and Buckley (2000).

The concept maps, drawn by the teacher educators, are generally in the categories of partially and poor understanding. Unfortunately, no one could draw a concept map on "models" which can be classified as sound understanding. It can be concluded, that teacher educators have superficial knowledge on models, since their concept maps include small number of concepts related to models. The most frequently expressed statements and concepts referred by the teacher educators on their concept maps were: (1) types of models such as mathematical models, simulations, mental models and scientific models, (2) the relationship between a model and the reality represented, and (3) the modeling process, which was drawn roughly. It is seen, that the types of models referred in teacher educators' concept maps were those they stated, that they were using in their courses in the interviews. Moreover, there has not been enough information about the characteristics and the objectives of models on their concept maps. Chang (2007) has investigated students' mental models through concept maps and also reported similar finding, that students used their life experiences to explain a science subject in their concept maps, although they did not have detailed knowledge about it.

The results showed that the teacher educators generally have two types of mental model of "model"; *proximate* and *goal oriented*. When we examined the teacher educators' mental models, it is seen, that the teacher educators who have *proximate mental model,* generally have drawn concept maps within the category of *understanding* or *partially understanding*. Besides, the other teacher educators who have *goal oriented mental model* generally have drawn concept maps within the category of *poor understanding.* It can be deduced, that there is a parallelism between the mental models of teacher educators and their concept map scores. However, the deficiencies of their concept maps may be stemmed from that the teacher educators have failed to reflect their knowledge exactly to their drawings. Teacher educators' knowledge on the nature of models, their characteristics, their types, and the modeling process need to be improved, because learning of scientific knowledge requires a better comprehension of the nature of models. Similar data obtained from earlier studies conducted with prospective teachers, teachers, and students may be indicative of the fact that there is a parallelism among the views of teacher, prospective teachers, students and the teacher educators' who have trained them (Van Driel and Verloop, 1999, 2002).

Conclusion and Implications for Teaching

This study has focused on determining teacher educators' views of "model" and their mental models. It was conducted with the teacher educators studying on primary and secondary science (chemistry, physics and biology) and mathematics education in different faculties of education. Regarding the obtained data, it can reasonably be argued that the explanations of the teacher educators on the nature of model and modeling have some deficiencies and are not at the expected level. This is because most of the teacher educators describe model as an instructional tool and fail to provide a scientific definition. Another supporting evident is that teacher educators give similar responses including unqualified explanations to the interview questions related to the general characteristics of them, and the objectives of using models. It can also be asserted, that teacher educators are not aware of the steps of the modeling process to set forth a model. It is also noted, that the teacher educators are able to express most types of models. Moreover, there is a parallelism between the models, which they have stated that they have been using in their lessons and those, which they have remarked their names in the interviews. However, it can be concluded that the types of models they used in their lessons are quite restricted than those they stated in their explanations.

It has been found out, that the teacher educators use quite small numbers of concepts in their concept maps during the interviews and generally put the types of models in those as related concepts, although they presented different views on models in their explanations during the interviews. It is also clear that their concept maps have been prepared superficially without giving information on the definition of model, its general characteristics or objectives, and the modeling process. On the other hand, their mental models of "model" which have been classified by taking their explanations and drawings in the interviews into consideration have dissimilar structures. It is found that most of the teacher educators have *proximate mental* model, and a small number of them have *goal oriented mental model*. However, there is only one teacher educator whose concept map is in the category of *understanding,* and there is no one whose concept map is in the category of sound understanding. The failure of teacher educators to set scientific correlations between the related concepts with "model" in their concept maps supports this result.

The missing or insufficient knowledge of the teacher educators who are employed in teacher training faculties on "model" shall regrettably affect prospective teachers, teachers, their teaching in their classes, and eventually their students. For this point of view, teacher educators, especially those in teacher training programs, should have enough information about the nature of models, their characteristics, their types, and the modeling process. Moreover, they should employ different models appropriately in their undergraduate and graduate classes. They should also emphasize the similarities and the differences between a model and the reality represented. Teacher educators should provide prospective teachers understand the fact that different models can be created for one single reality. This is important for both teacher educators and teachers because creating or using more than one model may be needed to explain the same fact, event, or theory to the students in science classes depending on students' different backgrounds and readiness level. A created model may not reflect all aspects of the reality represented, so teachers or teacher educators should be aware of that another model may be fruitful for explaining the properties of the reality to be learned by students. Furthermore, better recognition of modeling process may also assist teachers or teacher educators in using models appropriately in their classes. Hence, it is considered that the knowledge of teacher educators or teachers who employ models in their classes should be improved.

Considering the results of this study, it is suggested that teacher educators should not only follow the new trends, theories, methods, or the applications in science or mathematics education literature, but also employ these methods or techniques in their classes. They should be encouraged to employ different kinds of methods, different models, and the modeling process during their courses. Moreover, teacher educators should encourage their students that are prospective teachers, both by giving information about models, modeling process, and how they should use models in their classes, and also by using models properly in their undergraduate or graduate courses and setting an example for them. Thus, prospective teachers will find a chance to observe how models are used in teaching/learning environment, so that they may be more self-confident in using models and adopt to use models in their classes.

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