THE CONTRIBUTION OF MODEL TEACHING AND MATERIAL DEVELOPMENT TO PHYSICS TEACHING: FARADAY'S LAW OF INDUCTION

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Abstract. This study aims to enable the subjects of physics lessons to be understood easily and permanently, to help the students associate the subjects with life when they do their jobs, and to develop the feel that they can construct a material through the information they gain in Physics lessons. The sample group of this study consists of 20 teacher-candidates studying at physics teaching department, Faculty of Kazım Karabekir Education, Atatürk University. The study was conducted in four steps: the first step is to choose the material to develop the model, the second step is to describe the relationship between material development and the subjects of physics lessons, the third step is to present the teaching model in the class and report it; and the last step is to take the students' views on the model and modelling teaching. In conclusion, through this study the students take their own material to the classroom. Since they are responsible for all process from the construction of the material to its representation and reporting, the students have to use their all knowledge and experience. Semi-structured interviews carried out with the students have demonstrated that their levels of understanding scientific model development coming from history have increased, their high-level learning related to the physics subjects dealt with has occurred, and their self-confidence has also increased as they use their own skills and knowledge related to the topic.

Keywords: Faraday law, model teaching, teaching material

Introduction

It is of great importance to make Physics teaching effective and enjoyable in terms of both teachers and students. Since some subjects in Physics are abstract, it is rather difficult for students to comprehend these subjects. Therefore, in order to provide an effective teaching particularly while teaching abstract subjects in Physics it is very significant to priorities visuality as much as possible and involve the students into their own learning processes. One of the ways of providing that situation is the model teaching (Saari & Viiri, 2003).

The model teaching and teaching material development are among the indispensable factors that facilitate comprehension of Physics subjects. The students have to know how the models are constructed and how they are used in daily life in order to understand the Physics (Hestenes, 1992). Hence, use of analogy and models in teaching Physics are the significant topics commonly studied (Gilbert et al., 1998; 2000).

While teaching models and modelling, it is not enough to only know to what extent the students already have knowledge about modelling in order to construct modelling in a particular scientific topic. In addition, it is also of necessity to know what kind of notions the students' have of models. However, few studies conducted on the students' notions of models have demonstrated that the students have trouble detecting the models (Finegold & Smit 1993; Gilbert, 1997; Grosslight et al., 1991; Stephens et al., 1999).

There are great differences between the models that Physics teachers show their students and the students' notions of models (Table 1).

Table 1. Differences between the school science and students' everyday views about models (Saari & Viiri, 2003).

Models in school science	Students' everyday views about models
A scientific model represents a target that is known or unknown	A model is an object or an act.
The purpose of the model is to represent a target and to help in its conceptualization	The purpose of the model is that of copying.
A model gives us the vocabulary for discussing the structures and properties of the target.	A model's fitness depends on who is making the model, but the model has to be as accurate as possible
Models can be tested and changed according to the tests	A model can be changed if it contains errors or if its maker wishes to change it

The students generally think that we can construct the models of only what we can see. In physical sciences, on the contrary, the models are mostly related to what cannot be observed, even what we can imagine. Similarly, the students tend to believe that a model is an object or a tangible thing. However, in science the models are generally abstract. According to the students, the model is a thing that can be copied (e.g., drawing a picture of an object or a target); in science, the models are mostly used for making predictions about the structures and processes of the unknown objects and to describe them. In this sense, the students believe that there is a great harmony and simulation between the model and the aim described by the model.

By comparing different views explained in Table 1, it can be reached following conclusions on students' learning tasks; accordingly, the students should be aware that (Saari & Viiri, 2003): (1) models can be concrete or abstract rather than being simply artefacts; (2) models are used to represent a target (its structure and processes) rather than a copy of a target or its image; (3) a model simplifies its target rather than being an accurate copy of it; (4) a model can be used to predict and explain the behavior of its target; (5) models can be applied generally to a wide range of contexts rather than simply to the situation of immediate concern.

Literature has suggested different pedagogical ideas that can be applied in teaching the modelling. For instance, according to Van Driel & Verloop (1999), while teaching models the focus is generally on the content of the models being taught and learned; the nature of the models, however, is not saliently discussed. Van Driel & Verloop (1999) also report that the students are rarely involved in the process of construction and revision of the models. On the contrary, teachers assert that the models should be learned as static facts. Similar opinions are brought forwards by Harrison & Treagust (2000) suggesting that the students need time to make models and that the idea of modelling should be taught in a wide range of context. The same researchers also point out that the model development should take place when students learn unobservable phenomena (Harrison & Treagust 1996).

The teaching model to visualize the formation of Faraday Induction Current is serves an observable and tangible example. Therefore, this model developed as a teaching material is both an example of reality and its tangible and visual version. Teaching materials to be constructed for unobservable objects will enable high-level cognitive learnings (analysis, synthesis and evaluation) to take place as much as increasing students' levels of understanding. On the contrary, the students will have trouble understanding abstract concepts.

Most of the students are not able to explore abstract views on their own since they regard teaching materials as concrete copies. Hence, the teacher has a key role in carrying the scientific information. Although discussions made by students are significant for learning, teacher's guidance is highly necessary while learning such an abstract content. Then, the findings obtained from the studies on this topic have revealed that discussions made under the guidance of a teacher are the most effective way to reach the high level of investigation (Llewellyn & Hogan, 2000).

The steps of the model teaching

Selection of the material for the model teaching

The diversity of possible roles for models is commonly accepted in science. The purpose of the model teaching and material development is to make the complex events easy and evaluate them in terms of setup, representation and functionality. The complex events mean to make the abstract Physics topics visual like concrete materials (Francoeur, 1997). At the same time, the material should be such as to represent the topic dealt with and provide a basis for the interpretation of experimental results in terms of functionality (Bent, 1984). The material developed should have a role that involves the explanations regarding the Physics topic mentioned and provides meaningful learning (Tomasi, 1988; Erduran, 1998; Gilbert et al., 1998). Modelling-the production and organization of models, has occurred as the dynamic and non-linear processes in terms of the development of scientific knowledge (Leatherdale, 1974; Tomasi, 1988; 1999; Prather, 1992, Gilbert, 1993).

Three aspects playing a central role in development of the models and materials (modelling) in science teaching can be mentioned (Cosgrove & Schvaverien 1997; Gilbert, 1997; Gilbert & Boulter 1997; Erduran, 1998; Gilbert et al., 1998; Spitulnik & Krajcik, 1998; Greca & Moreira, 2000; Harrison & Treagust, 2000): (a) *To learn science*: Students should learn major scientific/historical models and know the scope and limitations of the models; (b) *To learn about science*: Students should have enough knowledge about the nature of the models. Furthermore, they should also know the role of the models in the accreditation and how the outcomes of the scientific investigation are disseminated; (c) *To learn how to do science*: students are required to produce, explain and test their own models. In other words, inasmuch as major scientific/historical models involve the current physics topics and support the necessary explanations and experimental results, the models to be constructed by the students should also possess these features.

That is also significant for teachers. The teachers observe the cognitive activities of the students in search of scientific or historical models and they, hence, can obtain the opportunity to observe the students' processes of modelling and their progress in the development of teaching models. In this way, they gain insight about at which stages the students have trouble.

If it is aimed to teach the Physics topic through the teaching model, processes of modelling development are also significant (Roth, 1985). How these processes should be need to be sought in the applications of guidance science.

It is clear that in the literature there is not enough information about how the teaching model should be. That probably results from the fact that there are no general rules for modelling, the development of teaching material is a skill and therefore should be learned rather than be taught. Meanwhile, it is also known that learning scientific modelling commonly take place in the curricula. Therefore, a way of modelling and material development should be discovered.

In literature, the steps of models and modelling are presented as in Fig. 1. Therefore, the model of modelling presented in Fig. 1 (suggested by Gilbert et al. (1998)) will be appropriate to be used for a purpose whether it be to describe a phenomenon, to establish the entities thought to consist (involving their spatial and temporal distribution), to attribute the causes and effects of that behavior, to predict how it will behave under other circumstances, or several or all of these. The person constructing a cognitive model of the model accepted from all perspectives to enable the topic to be learned, modifying an existing model, or creating their own model need to be clear as to the purpose of the related topic. Decision process and the student's idea for material development start with the script regarding the phenomenon that already exists. This process will be built with direct or indirect, qualitative or quantitative experience of the phenomenon. Furthermore, that is also related to the student's skill of observation. The relationship between the processes involved in the selection of the source and objective factors in the source should be similar to those in the target and its transfer to the model teaching should be also appropriate to the approach proposed as structuring map (Gentner & Gentner, 1983). After producing a model in this way, it is of necessity to take decision on whether the material will be represented visually, orally or mathematically (Boulter & Buckley, 2000). This process of expression appears cyclically in terms of the cognitive model and the act of expression also leads to a change in the model. After constructing a model or appreciating a scientific model, the following step is to explore its inferences through 'thought experimentation' conducted in the mind. As Reiner & Gilbert (2000) have interpreted, the scientists always mentally rehearse the design and implication of a model. However, it is only possible to test when the results of this mental activity seem successful. If the model fails to produce predictions confirmed in the testing phase of the thought experimentation, it is required to make an attempt to modify it and reenter the cycle. Nonetheless, if it passes the phase of thought experimentation, it can go on to the phase of 'empirical testing'. That first entails to design and conduct the practice study, then collects and analyzes the data and lastly evaluates the results of the model. If the model fails at this stage, it should be attempted to make modifications on it and re-enter the cycle. Nevertheless, if it passes the practical testing phase, the modeler will be sure that the purpose of constructing the model was fulfilled.

If all these come true, the following step is to make an attempt to compare the teaching model constructed and persuade others into its functionality and representation with a scientific/historical model. That is the process of advocacy, which reveals *the scope and limitations* of the model, leading to a reconsideration of the earliest elements in the model-production cycle. If the targeted results are obtained and a material appropriate to the target is formed, the model production takes place. In the opposite case, it is necessary to make some changes in the production of the model. These changes can be made on empirical testing phases as much as mentality. However, if the model repeatedly fails, it will have to be rejected. This will lead to a radical reconsideration of the earliest elements in the model-production cycle.

Construction of teaching material and description of its relationship with the topics of Physics

The material constructed as a scientific model or for the purpose of teaching should be a simplified version of the scientific model. The teaching material to be constructed should also represent a scientific/historical model. Glynn et al. (1994) have proposed a six-step introduction for any teaching material specially constructed. These six steps are: the introduction of the model; the introduction of the teaching material; the identification of relevant and corresponding features between the target and the teaching model; the mapping of the similarities between the two; and the identification of where the analogy breaks down; the drawing of conclusions about the nature of the target as modelled.

Whereas Treagust et al. (1996) have demonstrated how this procedure will be used successfully in terms of teaching material introduced or produced by the teacher; Pittman (1999) has showed that the students can successfully construct and use their own teaching materials. On the other hand, Idling (1997) has generally summarized good practice in learning through teaching models. Modelling requires obtaining a cognitive model. Since the target model at the center of attention is already completely developed and known by the teacher, all other features of the model of modelling will be suppressed. Of course, as the process by which the target model has been initially developed is 'cognitively reconstructed' (Nersessian, 1984), it is required to represent all the elements of the model of modelling framework to the students in a reasonably original way.

Preparing teaching model enables students to gain more skills than just learning the nature of a particular model. If this results in success, the students come to learn to develop skills of making the events regarded as abstract in Physics tangible. The model teaching applied in suitable situations provides high-level learning. Arnold & Millar (1996) used a series of combined teaching models so as to teach the concepts of heat, temperature and thermal equilibrium to 12-13-year-old students in England and following this practice, they asked them to use these ideas in other contexts. Halloun (1996; 1998) had students use scientific models while solving a series of sample problems in physics. On the other hand, in their studies on drawing of models in physics Karaman et al. (2003) required the students to model the movement of the molecules heated when water is heated. These studies mentioned above are the applications of the 'model of modelling' and what is emphasized in thought experimentation is to make the topics of physics understandable. Furthermore, this is also a sign of empirical experimentation on the application of the 'model of modelling'.

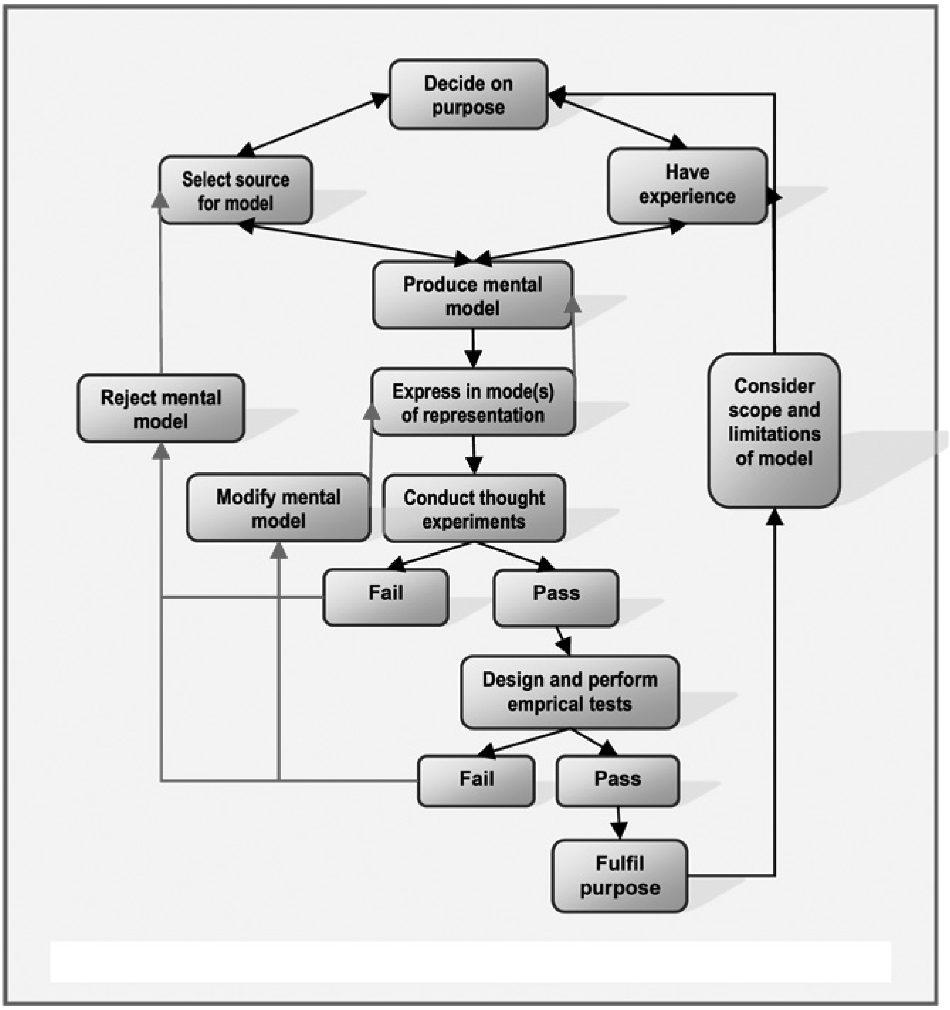

Fig. 1. A 'model of modelling' framework (Clement, 1989)

Introducing the material in class and reporting

Introducing the constructed material in class is the responsibility of the teacher. However, who will introduce are the students constructing the teaching model. This requires both the students and teachers to make good preparation and have planned lesson content.

Preparing teaching models (modelling) is a complex procedure and involves many component activities, one of which should be learned very well. Lehrer et al. (1994) have pointed out that the ability of model production requires a series of epistemological commitments. These commitments entails firstly to be able to appreciate the notion of separation between phenomena and noumena, that is, what is being represented- not the representation itself; secondly, the possibility of producing a representation through the development and application of a system of formal elements; thirdly, the notion of prediction using simplified representations that provide the opportunity to identify emergent behavior. If these epistemological commitments are acquired gradually, the students can see their progress in the framework of 'the model of modelling' outlined in Fig. 1.

Five approaches to learning about models and modelling that enable to acquire the abilities have been identified. Although these five approaches to acquiring the skills and epistemological commitments required in modelling seem distinct from each other, they are to a large extent only related to representational convenience (Justi & Gilbert, 2002a).

1. Learning consensus/curricular models, if necessary by means of teaching models;
2. Learning the use of models;
3. Learning how to revise models;
4. Learning the reconstruction of a model;
5. Learning to construct new models.

The aforementioned approaches to representational convenience will support the modelling to be learned by students. Learning to construct models seems a long-term and also haphazard process characterized as high-level of uncertainty, partial success and even failure. Inasmuch as modelling needs to be gradually introduced to the students, in this process the teachers are also required to teach what modelling entails in an appropriate way.

Reporting the study is proposed to record the stages of modelling constructed by the students, to have details of a well-planned study, to make association with the topic of physics to be explained through the constructed model and to represent the model as planned before. Moreover, for the future the students will have a ready resource to use while teaching by reporting the study of modelling conducted.

Research questions

How are the notions of students about modelling?

Does the model teaching contribute to better comprehend the abstract topics of Physics?

Does the model teaching make contributions to the development of the students' self-esteem?

Method

Sample group

The sample group of this study conducted by qualitative research design consists of 20 pre-service teachers studying at Physics Teaching Department, Kazım Karabekir Faculty of Education, Ataturk University in 2011 – 2012 academic year.

Process

Theoric information of the model teaching and material development were first provided for the participants. Then, the students were divided into 4 four group consisting of 5 students, each group was required to represent a teaching model they constructed on a topic in the classroom and find out the topic's usage in daily life by reporting their activities. In the light of these required activities, identifiyng their purposes and job-sharing among themselves, each group were asked to plan their activities for investigation, material development, representation and reporting during a one-term teaching and education period.

Conducting the activities in line with the plans, the data were collected through interviews with students and here was just mentioned about the model of a group concerned with Faraday's Induction Current in order to prevent the study to be broaden.

Data collection instrument

In this study, the semi structured interviews consisting of four main parts were used as a data collection instrument. Before taking the participants' views on the model teaching a pilot study was conducted and the last version of the interview to be used in data collection was, thus, identified. In the beginning of the interviews, the participants were clearly informed about the purpose of the interviews. The participants' views were obtained through revised interviews carried out to 8 participants. The data were recorded by taking notes during the interviews lasting about 25 minutes,.

Data analysis

Content analysis was carried out for data analysis of this study (Bardin, 1991). The interviews were transcribed and codes were obtained. The codes were presented as sentences.

Present four steps here

It has been thought that using the framework of the "model of modelling" constructed by Clement (1989) will be appropriate for this study (Fig. 1). In this sense, it has been believed that model teaching method and teaching material to be constructed in this study will make physics topics that are abstract and students have difficulty understanding more understandable.

Modelling: Faraday's law of induction

In this study, the students are asked to construct a model through which they will be able to explain Faraday's Induction Current visually. The purpose of constructing this teaching model is to teach Faraday's law of induction and show the students what to do in their daily lives through this law. The working principle of the teaching model will be based on electromagnetic theory. This theory is Faraday's Law of Induction discovered by Michael Faraday (1791-1867). According to this theory, a voltage is inducted in a static transistor in changeable magnetic field. The value of this inducted voltage depends on the speed of change in magnetic field at a unit of time and the number of coils of the transistor.

The students have stated to have learned Faraday's induction current in physics labs through the scientific/historical model. However, in this study the students were asked to construct a model similar to that model and to be used in daily life. It has been stated that while constructing this model, the stages theoretical basis of which has been explained above should be taken into consideration. In this sense, pre-service teachers were required to make the topic concrete constructing the teaching model of Faraday's Induction current, to represent it in the classroom, and to explore its usage in daily life reporting all the activities conducted. In line with this purpose, the students job-shared among themselves. The pre-service teachers were asked to gradually plan all the activities of making research for the model they would construct, representing it in the classroom and reporting them during the term.

Materials required for the teaching model

(1) A plastic pipe in 40 mm diameter and 18 centimeters length; (2) 4 neodymium magnets; (3)180 m magnet wire; (4) 1 bridge rectifier; (5) 1 LED; (6) a chargeable battery; (7) USB kit; (8) plastic protecting band; (9) a sponge.

Constructing teaching model

From the before-mentioned materials, the plastic pipe is firstly taken. Its nearly 3 cm part which will come up to its center is sculped in depth of 2 mm. This procedure enables not only the conducting wire to be coiled easily but also the coil made by the conducting wire to be more close to the magnetic field the magnet provides.

The conducting wire should be wrapped around the sculped-part. 180-meter-height wire constitutes 1200-wound-instructor. The conducting wire 20-cm-part from both sides will be left unwrapped. The rectifier, LED lamp, chargeable battery or a kit to charge a mobile phone will be put in these unwrapped parts. In addition, 4 neodymium magnets will be put into the plastic pipe (Figs. 2-6).

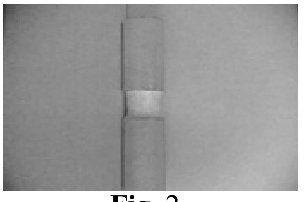

Fig. 2

Fig. 3

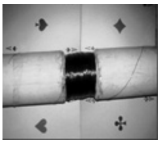

Fig. 4

Fig. 5

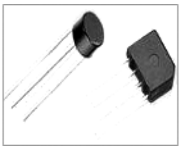

Fig. 6

Fig. 7

Fig. 8

Working principle of the teaching model

Faraday's Law of Induction" provides a basis for this teaching model. Moving inside the static conducting wire wrapped around the plastic pipe, the neodymium magnets (Fig. 5) changes the magnetic field and induct electrical voltage in the conducting wire. Inducted voltage accumulates in two empty points. The current in the conducting wire is alternating current. Alternating current is required to turn into continuous current to be used in electronic items. For this purpose, linking two points of the wire with the bridge rectifier shown in Fig. 6, alternating current is turned into continuous current.

Continuous current obtained through bridge rectifier is transmitted to the LED lamp. Thus, the LED shines in each shake. If the rectifier is not used, the LED will shine in unilateral transmission but not in other –sided transmission. Through the continuous current, the LED placed on the rectifier shines when shaking the material by confirming that the current constitutes. If wanted, the current in the wire is transmitted to the slot formed to charge the battery. The battery placed into the slot begins to be charged with the current that occurs in each shake. Instead of the battery, a high capacity condenser (capacitor) can be also charged in the same way. The teaching model, thus, functions as required. Owing to the kit placed on the tip of the charged battery (Fig. 7), electrical potential energy stored in the battery can charge the batteries used in mobile phones, MP3 players and Electronical items Fig. 8 shows the last form of the teaching model, Fig. 9 illustrates its schematic form.

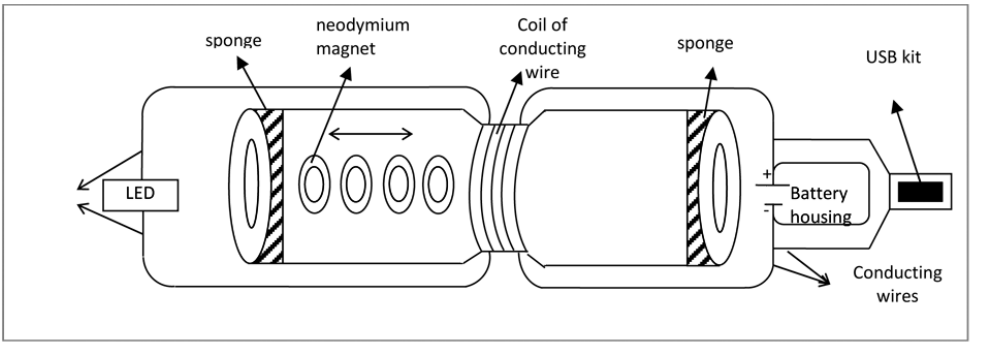

Fig. 9. Conducting sample

The teaching model to visualize how Faraday's Induction Current occurs serves as a concrete and observable example. This model constructed as a teaching material is, thus, both a simple form of the fact and its concrete and visual form. The teaching models to be constructed for unobservable objects can also provide such high-level learnings as analysis, syntheses and evaluation in addition to increasing the students' understanding levels. On the contrary, the students may have trouble understanding abstract notions.

The reason why Faraday's Induction Current is visualized as a teaching model in this study results from the fact that it is necessary to enable the students comprehend this topic regarded as abstract, the materials to be used in construction of the model are accessible, and several items constructed benefiting from Faraday's Law are commonly used in daily life. Furthermore, in this study it is also estimated to show the students that the topics of Physics to be taught are not only theoretical but also can be used in many fields of life and to make contributions to the development of their self-esteem by using information.

Results

Purposes for constructing model

A must for success necessitates that a modeler (a scientist or another person) should have a clear target in model production. In line with this purpose, responses of the students' interviewed are as follows: *The targets to construct a model should be clear and in what situation the models can be used should be known. It is of importance that you should keep in mind what opinions you try to explain and clearly state them.While constructing a model, it is significant to take its aims into consideration.*

The responses presented above are the results obtained from the students' views on the target. The modeler to construct teaching material has started to present some obvious views on the classroom, a described mass. Therefore, most of the responses given by the students are as follows.

For instance: *It may be possible to produce different models based on the levels of people to whom the model will be represented. The person producing the model should consider all the problems faced when the other people try to understand the model.*

The other purpose is regarding the extensiveness of the model. The students are of opinion that any model as complete as possible- that is, it presents all aspects of the notion- is the thing to be desired.

For instance: *In my opinion, a model should demonstrate all the details of a notion. I think that a model should point all main lines of an object or a notion one way or another.*

However, they have noticed that it is not always true.

For instance: *There is nothing as a complete model. The current models are those more complete and appropriate for a certain level of explanation than other models.*

In each situation, the model has to achieve, to a certain extent, similarity to the notion identified by the modeler. *It should be similar, as much as possible, (to the notion) so as to provide a better understanding. What is different is the complexity of the model. Everybody can make a model of something in a way that it will be convenient with their own reality knowledge. Anyone else can produce a model different from mine. It may be better or worse than mine depending on both the level the person has and the difficulty that model requires.*

It may be possible to think different models; even some may be more complex than others.

Experience, knowledge and characteristic of the modeler

The participants have given following responses to the questions on experience, knowledge and special talents of the individuals to construct a teaching model:

For instance: *Another person may produce a model different from mine. That* *relates to the individual's experience with the notion that is being modelling.*

In addition, the experiences with the other notions and models may be also beneficial.

For instance: *I believe that others may produce a model different from mine since personal effects may influence the model. Everyone is tending to make comparison with those they have experienced before. Scientists have other models with which they will make associations. In my opinion, a scientist attempts to organize his opinions and make associations with what he already knows so as to demonstrate what he thinks.*

It has been seen that success in modelling is closely related to individual features of the modeler. The students' views on the question of "What are the characteristics of a successful modeler?" are: first, in constructing a model, the modeler has to have current knowledge and the scientists are more successful in this sense.

For instance: *I think, if interested in the topic, everybody can produce something. In my opinion, the model a scientist constructs is, of course, distinct from that constructed by an ordinary person. The scientists tend to be more careful in terms of reality, validity and trustworthiness. I think, when an ordinary person produces a model, he does not consider other subjects; however, the scientists are always concerned with extra things to be explained.*

Secondly, a successful modeler should be a successful person in broad sense. In addition, scientists have been thought to be more successful than other people.

For instance: *A person needs a lot of creativity to make a model of something. Even, the individual may have to apply his feelings. It is possible to make models more than one for a certain thing; because it (model construction) relates with how the individual thinks, what opinions he has and how creative he is. A scientist always has to be creative. After his first observations, he begins to construct simple models and at the same time to test them.*

I think, it is necessary to have creativity and courage to cope with new ideas.

Thirdly, the modeler should be decisive.*The person should be decisive, because he should not give up if the first model fails.*

Selection of appropriate material for model

In their responses to the questions on selection of material, the participants have stated that they have benefited from similar materials for both the topic and scientific/ historical modelling.

For instance: *When I have to make a model of something, I always think something that I know and will help me. When a scientist has to make explanation of something unknown, he tries to associate that with something known.*

The participants seem to have noticed the importance of similarity between the scientific/ historical modelling and their own teaching model. *It is significant to pay attention to use similar materials to those used while making the experiment of Faraday's Induction Current, because these materials are necessary to form current. While constructing a model, it is significant to consider its purposes and required level of accuracy.*

Some of the participants interviewed have proposed that there is a difference between a scientist' modelling process and their own modelling process.

For instance: *I think, the process of a model production followed by a scientist is distinct from that followed by another person. Because, a scientist always tests his model, develops hypotheses, analyzes each situation and controls whether the model meets a certain case. On the other hand, we make models by copying something.*

On the other hand, some students believe that the process is the same but the quality is different.

For instance: *In my opinion, while constructing a model both scientists and other people follow the same cognitive process. Differences result from the fact that throughout the process, the scientists observe the features of the notion in more detail and are more determined compared to other people.*

Other students could not make a clear distinction between scientists and others.

For instance: *First of all, the individual, whether a scientist or a student, needs to have some information on the topic of the model. Then, the individual has to create the model and confirm whether it is appropriate to the reality.*

In addition, some of the students have regarded modelling as an inductive process.

For instance: *The scientists firstly observe something, and then obtain concrete materials to reflect what he observes and convey their opinions on that to other people. Scientists gather a lot of information; since such a process is not easy, this task may sometimes last a lot. Then, they try to make complex things simple and produce models presenting their opinions in different ways.*

On the other hand, some participants have considered it as a deductive process.

For instance: *Scientists start with hypotheses, and test them in different situations; if the model can be repeated well as a result of these tests, a scientific law or model is, then, obtained.*

Most of the participants believe that deductive and inductive processes in modelling are intertwined.

For instance: *I think, a scientist tries to organize his opinions and associate with those he already knows in order to demonstrate what he thinks. Then, he will test his model against reality.*

Success in preparing a teaching material or constructing a model is related to having a clear view on the approach to the accepted task. In other words, if those who plan to devise a teaching material or to construct a model firstly have scientific knowledge about the topic and perform the task thoroughly, success is inevitable.

Use of an appropriate way of representation

The students interviewed have been asked questions on how representation should be and their views have been obtained. Furthermore, they have been also asked some questions on the visuality of the material to be applied in representation. The students have emphasized that using material when possible is significant while explaining the topic.

For instance: *If a notion is not abstract, it is significant to see and hold the object.*

The students have stated that explaining the subjects, particularly abstract subjects, by modelling is better.

For instance: *Making the model of an object is more difficult than making the model of a process. For instance, while making a model of a car, I just observe it and then make its miniature; however, I have to imagine the moves of electron in atom.*

On the other hand, the students' views on making abstract and invisible physics subjects concrete and visible, thus making the representation more understandable, are as follows: *I think, a model should make a thing to be modeled visible. I have some information about the moves of electrons in atom, no matter how difficult it is to make its model; I need to make these ideas concrete.*

The teaching material or the model constructed should be tested experimentally. It should be compared to the results of the historical/scientific model. If the results are successful, there will be two questions to be answered in the process of explanation. How should the person making the representation state his/her views in different ways? The students' views regarding the characteristics of the person to make the representation are as follows: *The individual may express his/her opinions in different ways. S/he should keep in mind what opinions s/he tries to explain and state them in a clear way. If the model is qualitative, the person should demonstrate* *its association with the topic and state it one way or another. If the model is quantitative, the person should translate what s/he sees into a different language. It is significant to make the created things and opinions visible.*

The interviews do not contain any questions that ask students to reject or modify an individual cognitive model. Therefore, the study has obtained no data regarding that feature of "the model of modelling".

Discussion and conclusion

In terms of students, it is of great importance to teach the topics of Physics through constructing teaching model. In such learning, the students themselves use the abstract notions and formula in the teaching material and thus learn. Experiential learning (learning-by-doing) is also known as structural learning. The best teaching method advocating such learning is teaching by models. Many researchers studying on learning, teaching and education have differently named such learning. Whereas some of them call it as model and modelling (constructing a teaching material), the other have used such names as effective learning, cooperative learning, and structural learning. This study is believed to provide permanent learning.

If a student wants to learn a scientific/historical model successfully, s/he should have those: understanding the scientists' views on the structure of that model, enough experience with the notion being represented, knowing why the model is constructed and what should be learned, understanding how similarities and comparisons are demonstrated, and knowing the material from which the target model and/or teaching model is constructed. In such practices, one of the compulsory conditions of learning is that the teacher is capable in all these features of modelling. In their study concerning this subject, Justi & Gilbert (2003) have reported that the teachers do not have satisfactory knowledge on historical/scientific structure of model and suggested in-service training for teachers so as to overcome that.

If a student needs to learn to use an identified model, s/he, then, needs to know all conditions mentioned above. Furthermore, the students should know how thought experiments are designed, how practice and evaluation will be and also construction steps of learning transfer while using a model. Education faculties should allow for activities to provide opportunities for developing teaching materials. In research regarding this topic, it has been observed that the teachers do not have enough skill of thought-experiment (Reiner & Gilbert, 2000). That is the notion confirmed here temporarily. It is also suggested that thought experiment should be involved in the list of teacher education themes. Since most of the experiments regarding the topic dealt with in several education faculties seem to confirm the practice (Wellington, 1998), it has been seen that graduate teachers do not have enough skill of model teaching.

Students have some deficiencies in how to revise a model and how to modify it. They should first have knowledge about development steps of cognitive/historical model and restructuring it as consciously (Nersessian, 1994). There have been some studies on consciously restructuring of all the main models in historical order (Justi & Gilbert, 2002a). Although they are available, use of mixed models in teaching hinders their use effectively (Justi & Gilbert, 2002b). If a student follows such a historical order, s/he will gain new experience in terms of pre-steps of model learning, and s/he will also gain required skill of evaluating scope and limits of the models. That is of highly importance for teacher-candidates.

After teachers have accepted that students are well-prepared for applying first three steps of modelling and proficient in all of these, the progress should be relatively linear towards the last two. Following that, learning construction of new models will be the last step. Students will be working like a scientist without knowing the result. On the other hand, main trouble for the teacher is time management since remodeling cannot be fit into schedule.

It has been also seen that developing teaching material enables the students to have positive attitudes towards the Physics. In addition, modelling shows the students that the topics of Physics are not just limited in what is written in books; and also shows how these topics are used in everyday life. The world technologically developed is understood by the students and their attitudes to technological developments, thus, change. Besides changing the students' attitudes to the Physics positively, that situation also raises the wish to learn the topics of Physics.

The students who have succeeded developing teaching material have the feeling that they themselves can also do something. When assessed individually, the greatest acquisition is probably that phenomenon. That phenomenon develops the feeling of being able to do, to comprehend and succeed in all their life.

Teaching some topics of Physics through teaching materials will also contribute to learning to occur at the level of analysis, synthesis and evaluation. The students developing teaching material internalizes the Physics topic taught and sees that his all learnings have a practice field.

In this study, learning the subject of Faraday's Law of Induction is provided in a different way by model teaching and developing a teaching material. The interviews carried out with students have demonstrated that use of model teaching has many advantages for teaching Physics and that is highly significant for the institutions training teachers.

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