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THE IMPORTANCE OF MODELLING IN SCIENCE EDUCATION AND IN TEACHER EDUCATION

MODELLEME YÖNTEMİNİN FEN EĞİTİMİ VE ÖĞRETMEN EĞİTİMİNDEKİ ÖNEMİ

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ABSTRACT: As one of the main disciplines, science is very important for people to make sense of their life. The appropriate use of the models in science classrooms to promote children's understanding, imagination and creativity definitely depends on the teachers who have experience of differentiating the scope and the limitations of the models. From this respect, the education given to pre-service student teachers in teacher education institutions as a base of the teaching profession should be considered carefully. Therefore, in this paper, the main aim is to indicate the importance of modelling in science education and in teacher education.

Keywords: Modelling, models, science education, teacher education.

ABSTRACT: Temel disiplinlerden biri olan fen bilimleri, insanların yaşadıkları dünyayı anlayabilmelerinde çok önem taşımaktadır. Fen bilgisi sınıflarında modelleri uygun bir biçimde kullanmak suretiyle çocukların anlamalarını kolaylaştırmak, hayal güçlerini ve yaratıcılıklarını geliştirmek modellerin kullanım alanlarını ve sınırını ayırdetmekte deneyim kazanmış öğretmenlere bağlıdır. Bu bakımdan, öğretmenlik mesleğinin temeli olarak öğretmen eğitimi kurumlarında öğretmen adaylarına verilen eğitim dikkatli bir biçimde gözden geçirilmelidir. Bu nedenle, bu makalenin temel amacı modelleme yönteminin fen eğitiminde ve öğretmen eğitimindeki önemini işaret etmektir.

Anahtar sözcükler: Modelleme, modeller, fen eğitimi, öğretmen eğitimi

1.THE IMPORTANCE OF MODELLING IN SCIENCE EDUCATION

'*The greatest value of models is their contribution to the process of originating new ideas – developing the imagination*' (Pauling, 1983, in Glynn and Duit, 1995).

As one of the main disciplines, science is very important for people to make sense of their life. According to Conant (1951: in Jenkins and Whitfield, 1974: 11) science is viewed as 'a way of explaining the universe in which we live'. Scientists develop interconnected series of concepts and conceptual schemes through observation and experimentation. Scientists' science, therefore, can be defined as a combination of imaginative, curious and logical thinking used in the production of new ideas.

On the other hand, children, like all human beings, have some views about science through their experiences and relations with the world in which they live. There are some similarities between scientists' and children's behaviour and thinking, such as a shared curiosity about the events that occur around them (Osborne, and Freyberg, 1985). From the earliest days of their life, children curiously try to find the meanings for the phenomena happening around them. The ideas of children and scientists are not however at the same level although the ideas of children are influenced in expected or unexpected ways though their experiences. Like scientists, children are also resistant to changing their intuitive ideas. As Selley (1986: 124) indicates, 'for the individual, what is true is what he has the best reason to believe'. Therefore, science education is vital in opening the doors from which children explore their intuitive ideas, discuss, and try to find more appropriate ones and elaborate their ideas. According to Gilbert, Osborne and Fensham (1982) the aim

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of science education is viewed 'as the development of children's science'. It is not saying that science education aims to develop children's views completely the same as scientists' views. Rather, it aims to 'obtain a coherent scientific perspective which he understands, appreciated, and can relate to the environment in which he lives and works' (Gilbert, Osborne and Fensham, 1982).

From my point of view, science teachers are the foremost people who can ensure the correlation between children's and scientists' ideas through their subject matter knowledge derived from scientists' views, curriculum knowledge, and pedagogical content knowledge (Figure 1). Despite the teachers' intentions in teaching science, the instruction given, the language used and the experiments carried out in science classrooms, children still have problems regarding understanding of science. One of the reasons for these problems, that has already been mentioned, is that children's ideas are not taken into account in science classrooms. As Osborne and Freyberg (1985) point out, from the constructivist perspective, it is accepted that the learning of science is improved when science teaching begins from the basis of children's ideas. Children's ideas should not be viewed as 'wrong ideas' because, according to historical evidence, it is suggested that there are similar ideas which were shared by earlier scientists (Gödek, 1997).

If we think of the atom theory, there are various models and explanations provided by earlier scientists; however, we cannot say that any of them is wrong. Each of the explanations and models was necessary to understand the full structure of the atom. Similarly, I would suggest that children's ideas should be recognised and considered by teachers to promote their imagination, curiosity, creativity and logic, and children should be helped in constructing and elaborating their ideas.

On the other hand, to cure the patient does not mean to diagnose the illness, rather, what the doctor needs is to find out ways of producing a recovery. Teachers not only need to diagnose or consider the chil-

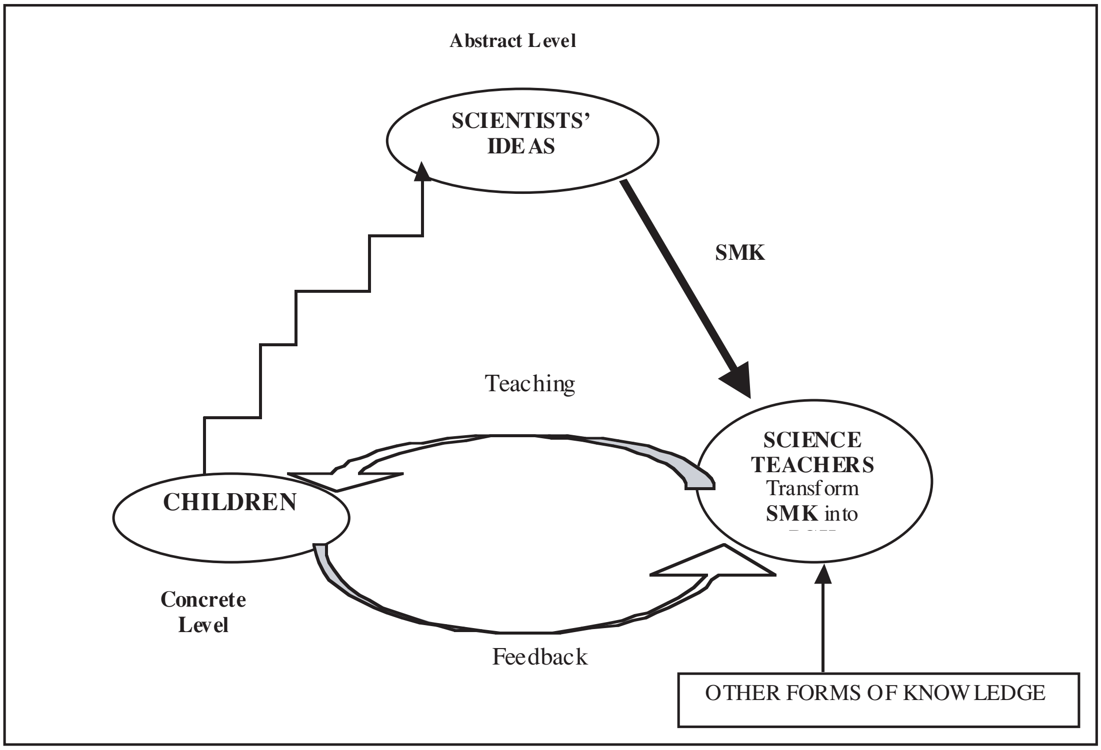

Figure 1: The transformation of Subject Matter Knowledge (SMK) into Pedagogical Content Knowledge (PCK) in science education (Source: Gödek, 2002: 43)

dren's ideas, but they also need to know the strategies through which the children's ideas are constructed. In this sense, adequate pedagogical content knowledge by teachers is very important. In classrooms, teachers always need some tools including explanations, examples, demonstrations and illustrations to represent their ideas. Particularly in science: many scientific phenomena are difficult to explain, and sometimes impossible to demonstrate; for instance, in chemistry, atoms, molecules and bonds are very abstract to grasp, not only for children but also for the adults. Teachers who have adequate pedagogical content knowledge use certain models, analogies and metaphors in their explanations depending on the children's cognitive levels.

In referring to Conant's definition (1951, in Jenkins and Whitfield); 'science is a speculative enterprise', therefore, one scientific phenomenon can be explained through more than one model. According to Jenkins and Whitfield (1974: 20), a model is defined as 'a concept formed by making a deliberate analogy with a more familiar idea'. The relationship between the real world and models, explained by Selley (1986:122) as 'Critical Realism', is that although a real world exists 'out of there' (i.e. independently of human thought), there is no possibility of our ever knowing just what it is like. We can only hypothesize, examine our hypotheses for self-consistency, and devise experimental tests. In recognition of this change in meaning, the word "theory" is often replaced by "model"'. He also comments that the reality might be represented through two kinds of models, A and B. Model A has greater explanatory scope than Model B which 'may have some merits, such as greater simplicity or familiarity, which make it worth retaining' (Figure 2).

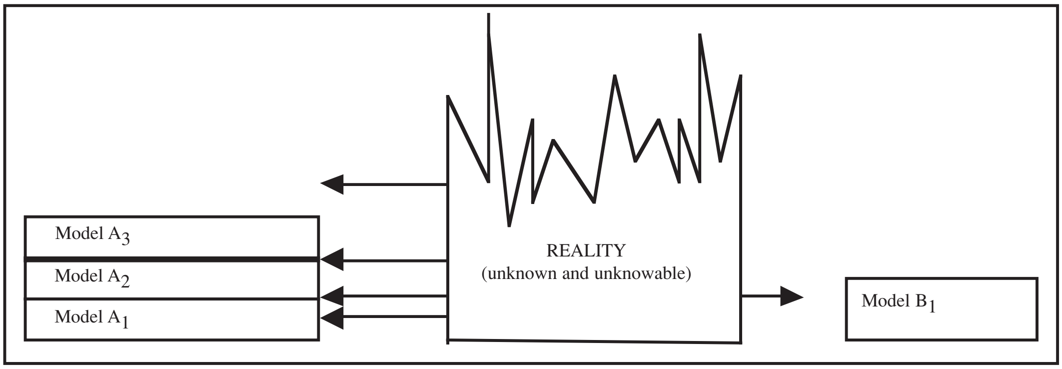

Figure 2: A Critical Realist interpretation of scientific knowledge (Source: Selley, 1986)

Models are being widely used in science and science education. There are some arguments about their necessity in science. For instance, Duhem (Hesse, 1963: 3) objects to the use of models in science, and comments that 'mechanical models … are incoherent and superficial, and tend to distract the mind from the search for logical order'. Similar points of view of other researchers were pointed out by Shapere (1965, in Jenkins and Whitfield, 1974: 21) that '…the model as an imaginative picture of how things really are only 'explains' in the rather unimportant and irrelevant sense of making things seem familiar'.

Nevertheless, I would like to discuss the issue of using models not in science but in terms of science education. I believe that models are very powerful bridges that make unfamiliar phenomena seem more relevant in science education and it is necessary to argue the degree of their usefulness rather than whether they are right or wrong. Models are powerful teaching and learning tools. However Duit (1991, in Thiele and Treagust, 1995), accepts that analogies [models] are 'double-edged swords' as they have both advantages and disadvantages. Jenkins and Whitfield (1974: 41) indicate that 'in science there is the ever present danger of children viewing models as "cast-iron" realities, a view which can act as an impediment in later learning'. A similar view is shared by Harrison and Treagust (1996). Gilbert and Osborne (1980) also point out that 'the misuse of models in science teaching can lead to misunderstandings by students of both models and their embodied concepts. Such misunderstandings are particularly important at the school/higher education interface as they contribute to later academic failure'. Moreover 'there is a risk that they [pupils] come to see science as untrustworthy, on the criteria that they have constructed' (Gilbert, *et. al*., 1998).

Significantly, models should not be seen as the reality or the theory itself, but they should be accepted and perceived as kinds of simplification or clarification of a theory. Therefore, teachers must be very careful when they use models. If the aim of science education is helping children to construct their knowledge, teachers must ensure that the models that they use in science classrooms should stimulate children's further investigation in constructing their knowledge.

Drawing an example, a dispersal model in which chemical interaction between the particles is not considered, is a widely used representation of dissolving (Figure 3). For example, mixing peas and rice can be a good analogy in explaining this phenomenon for children in a particular cognitive level. In this analogy, the spaces between peas are used to explain solubility. However, dissolving sugar in water is difficult to explain with this analogy, because it is difficult to understand the reason why sugar with a big structure dissolves in water which has a small structure. The dispersal model also gives no information about the structure and bonds of the compounds which are only represented by balls with different colours. In addition, through this model (peas and rice) it is also difficult to explain how the solution may become saturated.

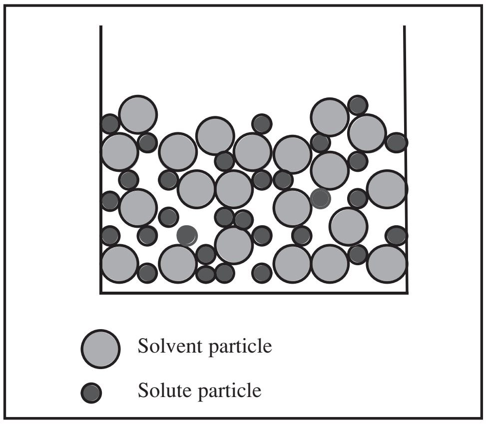

Figure 3: Dispersal Model (Physical change) (Source: Gödek, 1997).

On the other hand, the chemical model is known as a powerful and alternative model for explaining dissolving; however, this model also has strengths and weaknesses. The study (Gödek, 1997) carried out on the explanations and models provided by twenty eight degree level chemistry books, demonstrated that the rule of 'like dissolves like' is commonly used. This rule seems very applicable in explaining the solubility of a compound which has similar polarity and forces; however it prevents understanding of the solubility of compounds which have different polarity and different forces. For an example, although having similar polarity, olive oil does not dissolve in water.

At a still more advanced level, mathematical models such as $DG = -RT \ln K$ and $DG = DH - TDS$ can be accepted as most powerful predictors of dissolving. These representations mean that a small amount of energy supplied from the increase of the entropy of surroundings, magnifies the solubility effect. A small change of the system's enthalpy gives massive changes in solubility. So, we can say that the driving force of dissolving is the change of the system's entropy while the modifying force is the enthalpy change (Gödek, 1997). Therefore, through mathematical representations dissolving could best be explained in terms of changes in system's entropy and enthalpy. However, the mathematical model also has weaknesses, because it is very difficult for children to conceptualise the terms entropy, and enthalpy and so the mathematical formulae.

Each of the models mentioned here has different strengths but they seem to compensate for each other's weaknesses. It is also evident that there is a hierarchical order in the use of models. I believe that each of these models can be accepted as building steps of the stairs (Figure 4). Therefore, it may be logical to use the terms 'more appropriate explanation or model' that compensate for the needs of the questioner rather than to offer 'best explanation or best model'.

A more appropriate explanation or model should be based on these questions: for what reason and for whom should the explanation be made? (Gödek, 1997). These questions are very necessary in the successful representation of pedagogical content knowledge. Consequently, the appropriate use of the models in science classrooms to promote children's understanding, imagination and creativity definitely depends on the teachers who have experience of differentiating the scope and the limitations of the models. From this respect, the education given to student teachers in teacher education institutions as a base of the teaching profession should be considered carefully. In the next section of this paper, implications for pre-service teacher education, teachers and future research will be discussed.

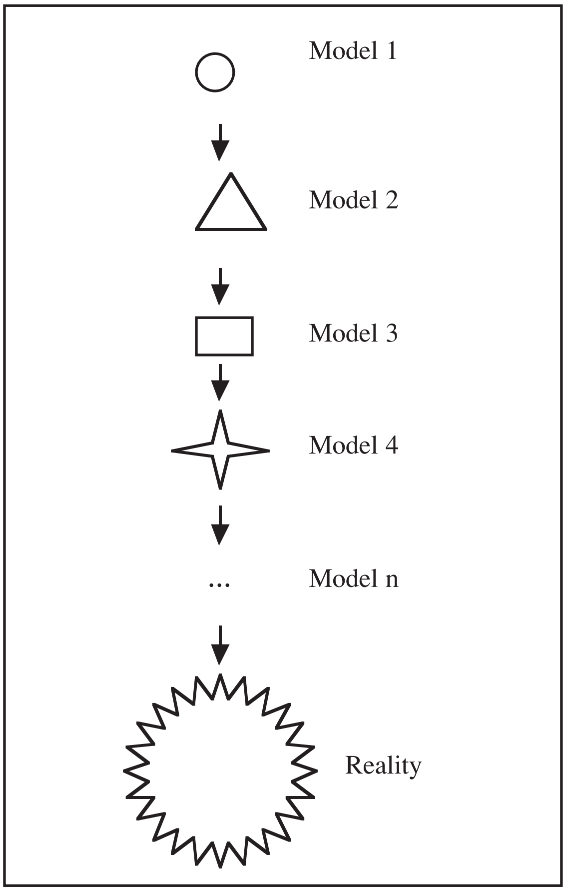

Figure 4: Development of models from very simple to complex.

2. IMPLICATIONS FOR PRE-SERVICE TEACHER EDUCATION AND TEACHERS

Science, as one of the most important disciplines, encompasses our lives. In the ever-changing scientific and technological world, the teaching and learning of science is very important. There are many scientific concepts and phenomena which are not directly observable. The representation of scientific concepts and phenomena in the real world is very problematic; however, adequate pedagogical content knowledge seems to offer opportunities for science teachers in teaching science effectively. As Hopkins et. al. (1994) state, the professionalism of teachers depends on the degree of their "artistry". To me, the artistry of teachers depends, to an extent, on consistent and strategic use of pedagogical content knowledge through utilising various strategies, models, explanations, analogies, and illustrations in relation to the learners' capabilities.

However, how we can educate teachers so that they will have an adequate knowledge base? There are some suggestions made by different researchers. Geddis (1993) suggests, 'Teacher education programmes would do well to devote more attention to the manner in which teaching implies the transformation of subject-matter, and of the critical role that pedagogical content knowledge plays in this transformation'. From a similar perspective Loughran (1997: 68-69) accepts pre-service teacher education programs as 'the first place of contact between beginning teachers and their prospective profession'.

> '*If they are to value the pedagogical knowledge that is continually being developed, refined and articulated within their profession, if they are to understand the complex nature of teaching and learning, and if they are to be 'teachers' not 'tellers', 'trainers' or 'programmers', then this first contact through pre-service programs is crucial. The pedagogy involved in teachers is very important' (Loughran, 1997: 68-69).*

Therefore, the role of teacher educators in teaching their students the effective ways of teaching and learning is undeniable. Teacher educators should involve student teachers in the kind of reasoning required for determining the appropriateness of representations in teaching, as well as help them attain the kinds of knowledge demanded to do so (McDiarmid, Ball, and Anderson, 1989).

Abell and Roth (1992) more specifically advise that 'science content courses for preservice elementary teachers may be more effective if they are taught in conjunction with science methods courses instead of separately and prior to the methods course. As concepts are constructed in the content course, appropriate elementary teaching strategies addressing those concepts can be practised in the methods course'. Therefore, science content courses in pre-service teacher education should involve appropriate teaching strategies rather than just focussing on theory of content.

As has been shown, there are similarities and discrepancies between children's and scientists' views. Children have difficulty in relating the explanations and representations provided by teachers with their views and their everyday life experiences. School science content needs to be given in more comprehensible forms through relating it to everyday and non-laboratory experience. It is necessary for teachers to avoid presenting science 'as entirely a pre-existing, non-negotiable body of concepts and theories' (Selley, 1986: 123). Teachers should be aware of children's views and encourage them to express their views. Teachers should listen, be interested in, understand and value the views of children and then decide what to do, and how to do it. According to Gilbert, Osborne and Fensham (1982) 'This is a major challenge for science teaching'. I believe that in this way, children are motivated to be creative, imaginative, and more responsive to learn science.

However, just exploring the views and misunderstandings of children is not sufficient for effective science teaching. There is extensive research on children's conceptions of the scientific concepts although there is a requirement to find out the strategies for eliminating those misconceptions. These strategies should depend on the cognitive diversity of children; therefore, as Shulman suggests (1986), 'the teacher must have a flexible and multifaceted comprehension, adequate to impart alternative explanations of the same concepts or principles'.

According to Roth (1999: 187), a 'well-designed orientation to new information, frequent review, multiple learning tasks, guided practice, use of engagement in appropriate material, and highlighting key concepts in making use of appropriate metaphors' are important techniques that effective teachers utilise in making their subject matter clearer for a variety of contexts and children. Therefore, direct experience and reflection based on models and explanations relating to the same topic for student teachers should be given in teacher education institutions. This view has also been suggested by Newton and Newton, (1995); Gilbert, Boulter and Rutherford, (1998) and Geddis (1993).

On the other hand, Harrison and Treagust (1996) make two suggestions. Firstly, 'some science instruction time should be devoted to the development of student modelling skills'. Secondly, 'whenever an analogy or model enters the classroom discourse, teachers should consciously ensure that the analogy is familiar and that they make effort to identify both the shared and unshared attributes with the students'. The main point of their suggestion is 'direct, content-specific discussions' of the children's 'conceptions of scientific models, metaphors, and analogies' or 'metacognitive reflections on the nature of science itself'. Harrison and Treagust (1996) also recommend that 'science curricula include explicit instruction in scientific modelling and that analogies, metaphors, and analogical models be presented in a systematic manner'. This view is supported by the suggestions for teachers and textbook authors made by Glynn, Duit and Thiele (1995: 249), 'the better solution is to introduce teachers and authors to a strategy for using analogies systematically to explain fundamental concepts in ways that are meaningful to students because the strategy allows students to construct new knowledge by comparing it to their prior knowledge'.

After all, children should be encouraged to actively apply, evaluate, revise and construct their knowledge, and relate it to their experiences. In this revision process, the task of children should be viewed as Selley (1986: 124) suggests: 'an improvement rather than a correction'. Gilbert (1993) suggests that teachers need to provide an environment for children to apply their models to the specific phenomenon, and then they can enable the children to see the limitations and the scope of their models and also of their own explanations. After this process, children are able to consider alternative models offered by their teachers. This will help them to construct their new models and knowledge.

From the research perspective, as Shulman (1986) pointed out, collecting, collating and interpreting the practical knowledge of teachers are all necessary. As Geddis *et. al.* (1993) indicate, there is very limited detailed study on pedagogical content knowledge operated by teachers to transform their subject matter knowledge. For future research, the exploration of what teachers do in classrooms, and a more adequate definition of the subject matter of the teacher education curriculum regarding science topics, as well as other domains, are also suggested.

3. CONCLUSION

In this paper, it has been tried to emphasise that the role of teachers should not be assumed to be transmitters of knowledge. The new changes in society, science and technology require teachers to be facilitators and mediators of information, and knowledge counsellors and leaders of life-long learning. The shift from the transmission of knowledge to the organisation of the pupil's learning requires teachers to have more responsibility for the organisation of the content of learning and teaching. I believe that approaching complex educational problems with superficial solutions is not reasonable; however, as I intended to emphasise in this paper, educational standards can be improved through:

- Deliberative consideration of the teachers' knowledge base including pedagogical content knowledge by teacher educators and policy makers;
- Effective transformation of subject matter knowledge through appropriate use of models and explanations by teacher educators and teachers.

I believe that the change in traditional views of teaching about teaching and learning can only be achieved in teacher education institutions where individuals take an active part in constructing their knowledge. Similarly, learning about teaching should be regarded as Loughran (1997: 65) suggests, 'student-teachers continually placed in situations whereby they learn through being in a learning position, learning through the experience by being in the experience. If they are to understand how a teaching strategy influences learning, they need to experience the teaching strategy as a learner'. Therefore, the transformation of subject matter knowledge through use of models should be experienced by student teachers and they should be challenged to relate to the theory and practice of teaching and learning of science in teacher education institutions. I believe that this is one of the opportunities in solving the educational problems in science education and educating effective teachers.

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