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Student Mental Models Related to Expansion and Contraction

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Abstract: Following up on the effects of learning environments is essential to learning. The aim of this study was to examine students' mental models related to the concepts of expansion and contraction of materials. The population of the case study consisted of 155 students in a city center in Turkey. The data was gathered using open-ended questions that required a description or visualization of expansion and contraction. Data analysis was carried out in two stages. After coding results, the categories scientific, synthetic, and initial were established and applied to the answers. In light of the findings, students generally have initial mental models at low grade levels but synthetic mental models at high grade levels. The discrepancy is not a failure of the students but because processes of expansion and contraction of material cannot be grasped easily. Therefore, visual models and animations of the processes are suggested for future learning applications.

Key words: mental mode; expansion; contraction

1. Introduction

Research of students' preliminary understandings in science education shows that students face abstract concepts from an early age and experience a number of misunderstandings as a result (Nicoll, 2001; Canpolat, Pınarbaşı, & Sözbilir, 2003; Koray, Akyaz, & Köksal, 2007). Some studies report that such mistakes negatively affect the learning of basic science concepts in later years (Coll & Treagust, 2001; Özmen & Demircioğlu, 2002). One of the duties of teachers is to resolve students' misconceptions.

Fundamental science concepts take two dimensions, macroscopic and microscopic. Daily events are considered macroscopic; atomic, molecular, and electron-like particles and their interactions are microscopic. Interactions at the microscopic level include abstract concepts and mental configurations that students have difficulty forming, which has been emphasized in many studies (Novick & Nusbaum, 1978, 1981; Harrison & Treagust, 1996; Coll, 2008; Çökelez & Yalçın, 2012). For example, observations of students about the incompressibility of liquids and solids lead them to consider how the granular structure of the material shows continuity (Novick & Nusbaum, 1978, 1981).

It was emphasized that some students will argue that properties such as the expansion, contraction, and melting of material are about the atom (Andersson, 1990; Pereira & Pestana, 1991; De Vos & Verdonk, 1996; Albabese & Vincentini, 1997; Johnson, 1998); they perceive the atom as a round, hard and solid "something" (Griffiths & Preston, 1992; Harrison & Treagust, 1996). These kinds of perceptions may lead students to believe notions such as the bending property of materials being the bending of single atoms (Ben-Zvi, Eylon, & Silberstein, 1986). Such students do not apply correct meanings to the granular structure of materials during expansion, contraction, and melting (Ayas & Özmen, 2002).

The restructuring of scientific mislearning is a complex mental change (Ayas & Özmen, 2002). It may not even be realized until after the teaching of related lessons (Novick & Nusbaum, 1978). Moreover, some teaching practices and insufficient materials may lead students to develop non-scientific mental

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structures (Cin, 2007; İyibil & Sağlam Arslan, 2010; Kurnaz & Sağlam Arslan, 2009, 2010; Kurnaz & Değermenci, 2012). In this sense, the effects of teaching practices on the learning of fundamental science concepts have to be questioned and monitored for deficiencies frequently.

Student mental models related to the expansion and contraction of material, a molecular level event, are the focus of this study. A mental model is an internalized status of an object, event, process, or system; these are cognitive structures that do not require technical accuracy (Borges, & Gilbert, 1999; Clement, 1993). They offer opportunities for evaluation, estimation, and explanation (Rapp, 2005). When diversity of experience is considered, it is important to examine students' mental models to discern if theyunderstand a subject (Vosniadou, 1994; Wittmann, Steinberg, & Redish, 1999; Örnek, 2008).

2. Methods

A case study method was conducted within the scope of this research. Case studies allow scientists to examine a target situation in its original context (Yin, 2003). The special case of this study is the determination of mental models regarding the expansion and contraction of material.

Study Group

The population of the study consisted of 155 students (28 students in seventh grade, 20 in eighth, 29 in ninth, 26 in tenth, 21 in eleventh, and 31 in twelfth) selected using the purposeful sampling method in the academic year of 2012-2013 in a city center in Turkey. In Turkey students learn the topic in molecular level starting from the seventh grade. Thus, the study group was formed with 7-12 grades students.

Data Collecting Instrument

Mental models are correlated with the three specific dimensions of information: content-based, structural, and transactional (Hill, 2010). Kurnaz (2011) has defined content and structural information as theoretical components belonging to the modeled reality. The following research questions included in the study reveal theoretical and practical information that determines the students' mental models of expansion and contraction of material:

1. What is expansion?
2. Visualize the changes which will occur after the interactions between the molecules of a piece of iron when it is heated.
3. What is contraction?
4. Visualize the changes which will occur after the interactions between the molecules of a piece of iron when it is cooled.

Analysis of Data

Data analysis was carried out in two stages. In the first stage, the answers of students were labeled as correct, partially correct, partially correct but with an alternative idea, wrong, or missed. The two researchers conducted separate codings. The goodness of fit between the two encoders was calculated as 92 percent for description situations and 86 percent visualization situations using the reliability calculation formula of Miles and Huberman (1994). The mental models were revealed by comparing the descriptions and visualizations of the students in the second stage. The research of Vosniadou and Brewer (1992, 1994) was used during the model determination process (Table 1). As seen in the table, the primitive mental model reflects perceptions that do not overlap with school knowledge, the synthesis mental model reflects perceptions that partially overlap with school knowledge, and the scientific mental model reflects perceptions that overlap with school knowledge.

Table 1. *Mental Models Used in Analysis Process*

Mental Models	Content	
Initial model	Perceptions which do not coincide with the scientific knowledge	Those who have answers that are partially correct but with alternative ideas, wrong and missed answers for the situations of description and visualization
Synthesis model	Perceptions which partially coincide or do not coincide with the scientific knowledge	Those who have answers that are partially correct but with alternative ideas, wrong and missed answers for one or two of the situations of description and visualization
Scientific model	Perceptions which coincide with the scientific knowledge	Those who have answers that are correct or partially correct for the situations of description and visualization

3. Findings

Expansion of Material

The findings concerning students' descriptions of the expansion of material are summarized in Figure 1. Few students provided correct answers. Most student successes were only partially correct or partly correct with alternative ideas. In fact, more than 60 percent of tenth and eleventh grade students were only partially correct, and almost 40 percent of seventh grade students provided no answer at all. Examples of student answers are as follows:

- "It means an increase in the space between the particles of a material due to the vibration of molecules when it is heated and an increase in its volume" (C, Student 29).
- "It means an increase in volume of a material when it is heated. Like happens in wires in summer" (PC, Student 15).
- "Expansion of a material is the increase or decrease in its volume proportional to its expansion coefficient based on heat and energy" (PCIAI, Student 7).
- "It means an expansion in molecules of a material" (I, Student 110).

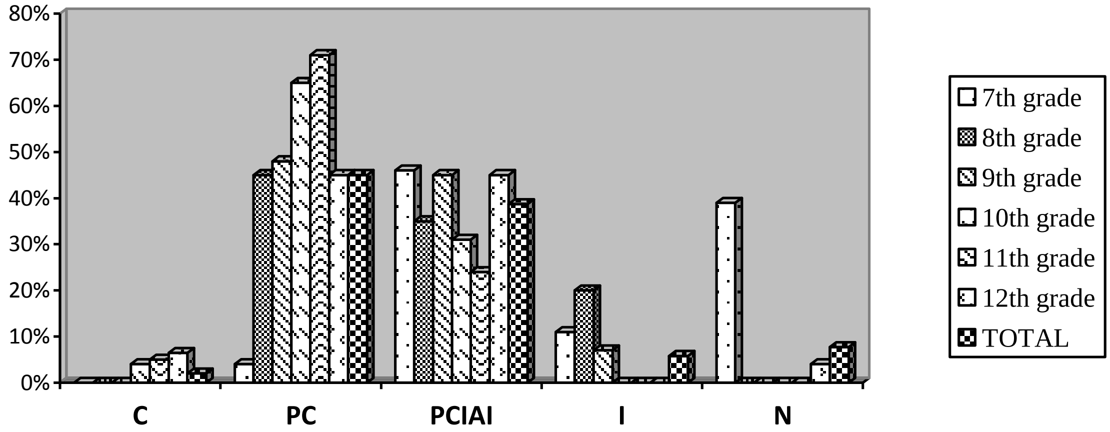

Figure 1. *Percentage distribution of student success concerning the description of the expansion of material.* C: Correct; PC: Partial correct; PCIAI: Partly Correct but also Including Alternative Ideas; I: Incorrect; N: No answer.

The findings concerning students' visualization of the expansion of material are shown in Figure 2. Again, few students drew the correct image; the only correct answers came from ninth and twelfth grade students. High results were reported in all grades across partly correct with alternative ideas and incorrect. Nearly 40 percent of seventh grade students failed to provide an answer. Some examples of student drawings are shown in Figure 3.

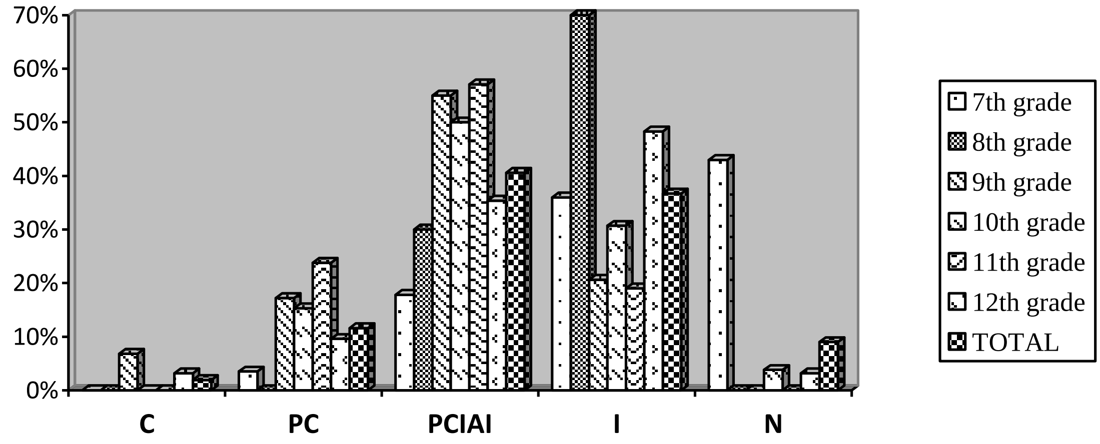

Figure 2. *Percentage distribution of student success concerning the visualization of the expansion of material.*

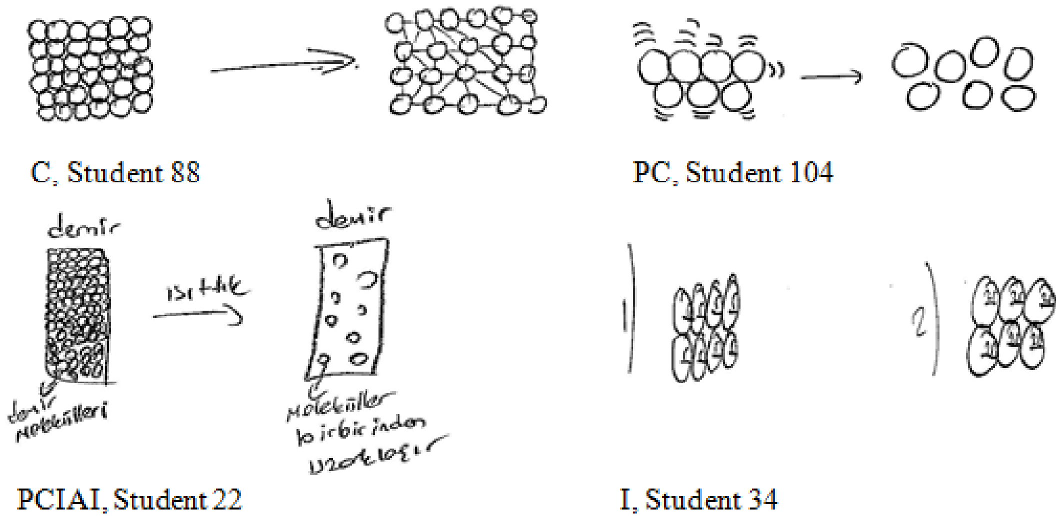

Figure 3. *Samples of case study student drawings of expansion.*

The findings concerning students' mental models of the expansion of material are shown in Figure 4. None of the students were grouped in the scientific mental model. A few matched the partly scientific mental model. The students in the partly scientific mental model lack alternatives ideas concerning expansion as well as a complete scientific perception. More than half of the students were included in the synthetic mental model, and remarkably, almost all seventh grade students were in the initial mental model.

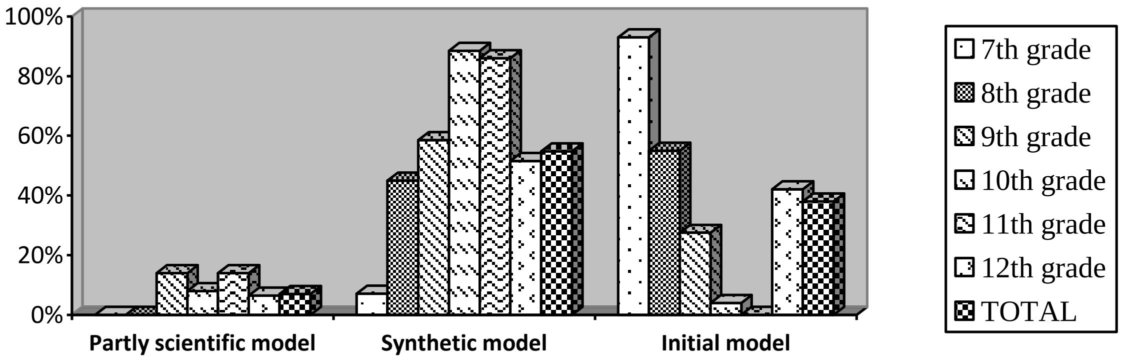

Figure 4. *Percentage distribution of students' mental models concerning the expansion of material.*

Contraction of Material

The findings concerning students' description of the contraction of material are shown in Figure 5. Few students answered correctly. More than 60 percent of eleventh grade students were partially correct, while more than 50 percent of seventh grade students and almost 40 percent of tenth grade students provided no answer. Examples of students' answers are as follows:

- "It means a decrease in the space between the particles of a material due to the vibration of molecules when its heat is decreased and a decrease in its volume" (C, Student 77).
- "It means a decrease in the volume of a material when it is cooled" (PC, Student 15).
- "It means a contraction in molecules and volume of a cooled material and a change in its shape" (PCIAI, Student 27).
- "It means deformation of a material by losing molecule" (I, Student 25).

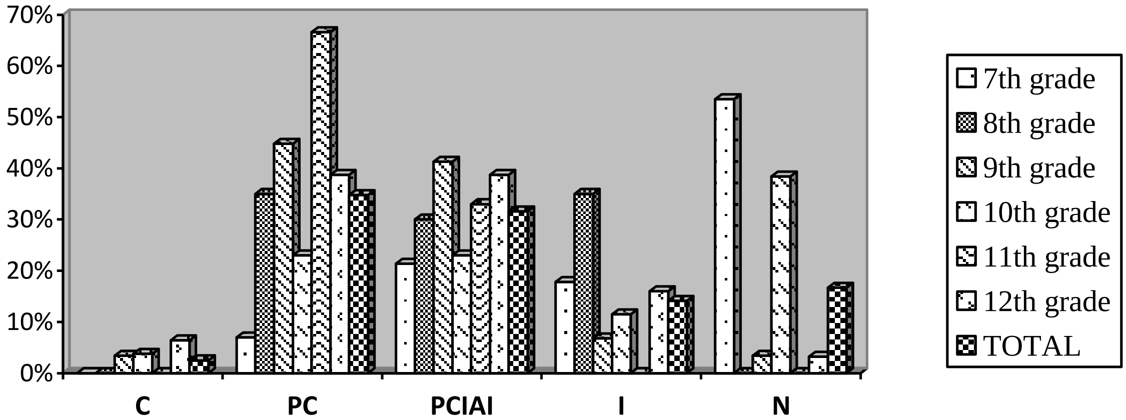

Figure 5. *Percentage distribution of student success concerning the description of the contraction of material.*

The findings concerning students' visualization of the contraction of material are shown in Figure 6. Once again, few students drew the image correctly, and none from the seventh, eighth, eleventh, or twelfth grades. Many students from grades nine, eleven, and twelve were partly correct with alternative ideas, while eighth grade students were mostly incorrect and seventh and tenth grade students did not answer. Some examples of students' depictions follow in Figure 7:

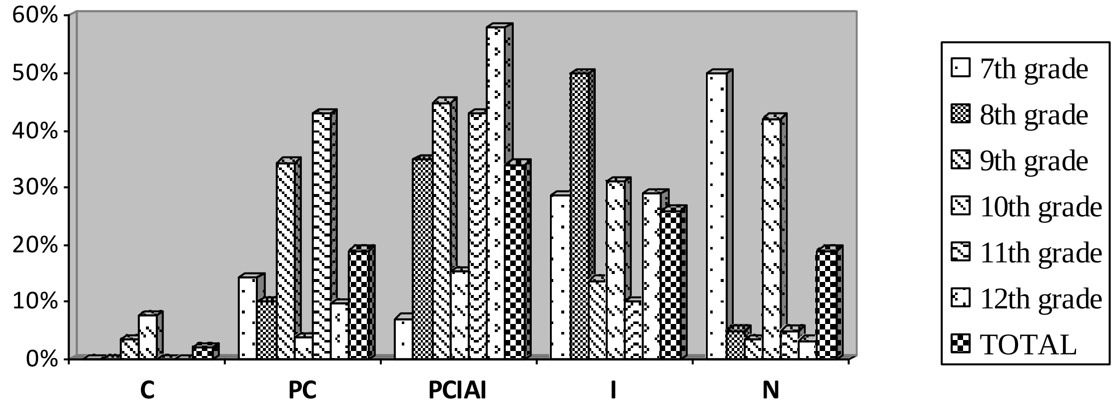

Figure 6. *Percentage distribution of student success concerning the visualization of the contraction of material.*

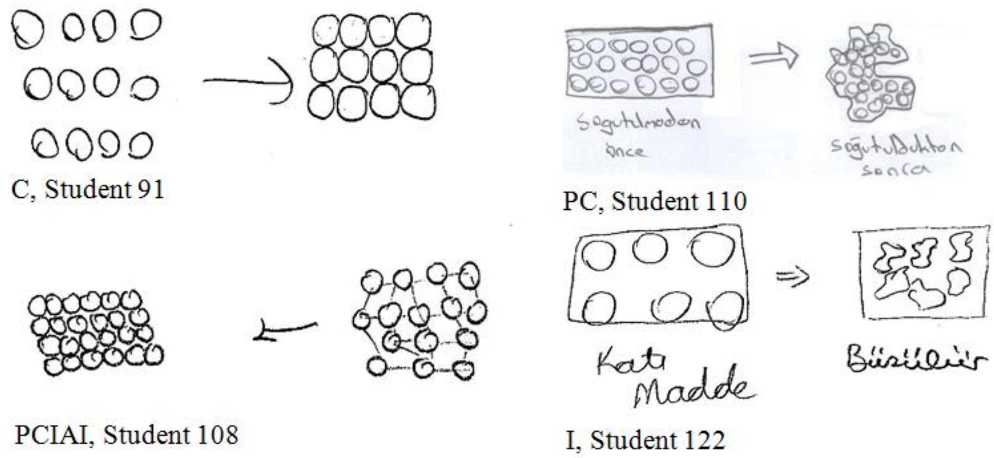

Figure 7. *Sample student drawings concerning contraction.*

The findings concerning students' mental models of the contraction of material are shown in Figure 8. None of the students are grouped in scientific mental model for contraction, either. Nearly one fourth of the ninth and eleventh grade students were in the partly scientific mental model category. Many ninth and eleventh grade students were also in the synthetic mental model, while the majority of the others were in the initial mental model category.

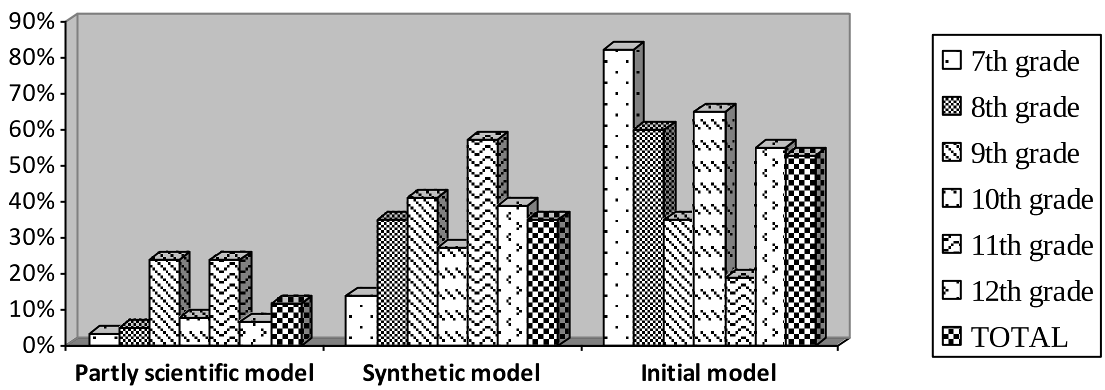

Figure 8. *Percentage distribution of students' mental models concerning the expansion of material.*

3. Conclusion

This study was carried out to determine students' mental models concerning the concepts of expansion and contraction of material. The findings are limited to the questions asked. According to the findings concerning the concept of expansion, students' mental models mainly follow the synthetic model. Lower grade students particularly fall under the initial mental model. In this context, students' mental models are far from scientific at early ages but become a little more so with school knowledge. In this regard, as mental models cannot gain completely scientific qualifications in the school, it raises the question whether current learning environments are sufficient. This idea becomes more meaningful when success rates of classes are compared. Students' verbal answers were more qualified than their visual answers. In other words, students had difficulty visually configuring the processes concerning expansion. Their drawings set forth that students generally perceive an increase in the number of molecules during the expansion process. On the other hand, a few students visualized an increase in spaces between the molecules by decreasing the quantity. The findings correspond with the literature (Andersson, 1990; Harrison, & Treagust, 1996; Coll, & Treagust, 2001; Ayas, & Özmen, 2002; Çökelez, & Yalçın, 2012).

On the concept of contraction, students' mental models were mostly in the initial mental model category, with the exception of the eleventh grade students. The decreased scientific nature is more apparent in lower classes. As seen with expansion, students establish non-scientific mental models at early ages but develop synthesis mental models with relatively scientific perceptions later. In this point, higher success rates in certain class levels can be explained by differences in qualities of learning environments, as mentioned above. As with expansion, students' descriptive answers were more qualified than their visual answers. Students had alternative ideas concerning contraction, such as molecules changing shape due to heat loss during contraction. When the findings concerning expansion and contraction were compared, students had particularly difficulty analyzing contraction.

In conclusion, although the mental models of the students in this study start to gain scientific qualification in direct proportion to their class, a complete scientific transformation does not take place. Students are not able to visualize the movement and structure of molecules during expansion and contraction. Thus, visual models and animations should be used to reflect macro and micro changes to aid the configuration of student mental models.

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