Examination of Visuals about Particulate Nature of Matter in Turkish Middle School Science Textbooks

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Abstract

Textbooks are one of primary teaching tools frequently used in schools and most of teachers take advantage of them in their classrooms (Sanchez & Valcarcel, 1999). Since there are a lot of abstract concepts in science education, images in science textbooks have vital role through learning process (Kenan & Özmen, 2011; Özalp & Kahveci, 2011). Concretization of abstract concepts may ease students' understanding. For this reason, the aim of study is to examine images about particulate nature of matter (PNM) in Turkish middle school science textbooks. In other words, visuals were examined with respect to representational levels, relatedness to text, existence and properties of captions. The rubric, which was developed by Gkitzia, Salta and Tzougraki (2011), was used to evaluate the images in selected units from middle school science textbooks. The results showed that totally 825 images were identified in related units at Turkish middle school science textbooks. In addition, it was found that the most common representation type of images about the PNM at Turkish middle school science textbooks is macroscopic representations (36%). Another consequence is about relatedness to the texts. It was reached that just four of 10 images are completely related and linked with the text. Lastly, it was concluded that more than half of images about PNM in Turkish middle school science textbooks have no caption.

Introduction

Textbooks are one of primary teaching tools frequently used in schools and most of teachers take advantage of them in their classrooms (Sanchez & Valcarcel, 1999). They facilitate students' learning not only as an information source but also help them to enhance their knowledge about the topic through samples and exercises (Nakiboğlu, 2009). Textbooks are also effective references about what students are going to learn, what teachers are going to teach and which instructional method will be used through learning process (Ertok Atmaca, 2006). For example, the study had done by Chiappetta et al. (2006) shows that 90% of teachers benefit from textbooks for organizing their instructions and to give homework. Therefore, textbooks have received a great attention by scholars in science education (Chiang-Soong & Yager, 1993; Çalık & Kaya, 2012; Dökme, 2005; Han & Roth, 2005; Irving, Savasci-Acikalin & Wang, 2006; Karamustafaoğlu & Üstün, 2005; Nakiboğlu, 2009; Niaz & Fernandez, 2008; Skoog, 2005; Şen & Nakiboğlu, 2012; Tekbıyık, 2006).

Images in science textbooks have vital role through learning process since there are a lot of abstract concepts in science education (Kenan & Özmen, 2011; Özalp & Kahveci, 2011). Most of students have difficulty to deal with these abstract concepts (Özalp & Kahveci, 2011; Zoller, 1990). Hence, concretization of abstract concepts may ease students' understanding. Images are beneficial tools to help more understanding of concepts, processes, and phenomena. (Kress & van Leeuwen, 1996). If the concept or process is impossible to observe or to try, tiny or thumping to examine in a classroom environment, representations (pictures, symbols, graphs, signs) play crucial roles (Buckley, 2000; Cook, 2006; Rapp, 2005). In addition, images are also used to motivate students by attracting their attentions (Cook, 2006; Pozzer-Ardenghi & Roth, 2005). Although there are a lot of studies which emphasize importance of images in education, there is relatively less research that investigates the role of multiple representations in science education (Roth, McGinn & Bowen, 1998). Whereas teachers, researchers and curriculum developers are aware of significance of visual representations theoretically, images have not reached their real potential in application at educational environment (Roth, McGinn & Bowen, 1999).

Multiple Representations in Science Textbooks

Textbooks are the most graphically populated print materials used for the communication and sharing of scientific ideas (Lee, 2010). If used well, they can be an effective tool to enhance teaching and learning (Nyachwaya & Wood, 2014). If the inconsistent uses of models (representations) in textbooks are adopted in classroom teaching, students' learning would be very problematic (Cheng & Gilbert, 2014). Most of studies about images in textbooks (Dimopoulos, Koulaidis & Sklaveniti, 2003; Gkitzia, Salta & Tzougraki, 2011; Han & Roth, 2005; Pozzer & Roth, 2003; Roth, Bowen & McGinn, 1999) found that most of representations in textbooks are photographs and pictures which are used mostly for macroscopic concepts or process. On the other hand, a common justification for multiple representations is using more than one representation simultaneously (Ainsworth, 1999). Ainsworth (1999) advocates that this catches students' attentions and enables them to translate between representation levels. They play an essential role in communicating disciplinary knowledge for students' learning (Cheng & Gilbert, 2015). Representations used in the books should facilitate students' understanding of chemistry concepts (Nyachwaya & Wood, 2014). Therefore multiple representations are powerful educational tools for students (Ainsworth, 2008). Diagrams, graphs, charts, equations, formulas along with words, photographs, illustrations and models can be examples for multiple representations (Kozma & Russell, 1997). Ainsworth (1999) states that multiple representations have three main functions as complementing, constraining and constructing roles in a learning environment. Complementary role means that different representations support and complete each other for the same knowledge or process. Constrain interpretation is either using more familiar representation or taking advantages of inherent properties of representations (Ainsworth, 2006). The last fundamental function of multiple representations is achieving deeper understanding by promoting abstraction, encouraging generalization and teaching the relation between representations (Ainsworth, 1999).

Fundamental Representation Levels in Chemistry

Chemistry relies on models to describe and explain all its chemical and physical changes (Harrison & Treagust, 1998). Wu, Krajcik and Soloway (2001) define chemical representations as various types of formulas, structures and symbols used to represent chemical processes and conceptual entities. In this context, multiple representations in chemistry education basically based on three main levels which were introduced by Johnstone (1993). He introduced macroscopic level that covers visible and tangible concepts or process.

Sub-microscopic level which depicts entities, too small to be seen with an optical microscope and the bonding within and between them (Bucat & Mocerino, 2009; Gilbert, 2010). Lastly, symbolic level that involves figures, signs, symbols, letters, equations, mathematical representations and formulas (Gilbert, 2010; Treagust, Chittleborough & Maimala, 2003; Wu & Shah, 2004). Furthermore, all these three representation levels are connected with each other. Whereas the macroscopic observable chemical phenomena are the basis of chemistry, explanations of these phenomena usually rely on the symbolic and sub-microscopic level of representations (Treagust, Chittleborough & Maimala, 2003).

All these representation levels have been used in different stage of a chemistry course. For example, Johnstone (2007) advocates that teachers must stay with macroscopic level until learners have formed new concepts before they attempt to introduce explanations of new concepts based on microscopic representations. It means that macroscopic representations can be used to teach fundamental concepts about the topic. On the other hand, traditional approach to teaching chemistry has not included particulate diagrams that stress the interaction of atoms, molecules and ions; however, it includes chemical and mathematical symbols and equations (Bunce & Gabel, 2002). This situation caused that students, who are successful at mathematics, seem to be successful at chemistry without understanding chemical concepts deeply. Besides, Harrison and Treagust (2003) advocate that students' attentions are at high level when macroscopic representations are used. Yet, it is difficult to maintain the attention while using sub-microscopic and symbolic representations. The reason of this condition may be due to intangible nature of sub-microscopic and symbolic concepts.

Particulate Nature of Matter

Particulate nature of matter (PNM) in science education curriculum covers matter structure and properties, states of matter and phase changes (Ayas & Ozmen, 2002). In order to be learnt about matter structure, the units related with particulate nature of matter are important (Snir, Smith & Raz, 2003). According to many of science education researchers, students must learn about particulate nature of matter successfully in order to achieve other topics such as phase changes, conservation of mass, chemical reactions, chemical bonding, ions, heat and heat transition, solution and diffusion (Adadan & Savaşçı, 2012; De Vos & Verdonk, 1996; Griffiths & Preston, 1992; Haidar, 1997; Lee, Eichinger, Anderson, Berkheimer & Blakeslee, 1993; Tsai, 1999).

The topic is also appropriate to use models in science education (Wu, Krajcik & Soloway, 2001; Yakmacı Güzel & Adadan, 2013) since modern theories about the structure of matter are too complex or abstract for most secondary school students (De Vos & Verdonk, 1996). Models and modeling are especially important in chemistry because chemical phenomena can be represented by concrete, visual, mathematical and/or verbal modes of representation (Akaygun & Jones, 2014). Thus, some researchers (Buckley & Boulter, 2000; Gustafson, Shanahan & Gentilini, 2010; Treagust, Harrison & Venville, 1998) have investigated about how non-visible particulates can be taught successfully by using models. Besides owing to the fact that PNM includes many concepts from sub-microscopic and symbolic levels, students create their own mental models about the topic. Mental models are intrinsic descriptions of objects and ideas that are unique to the knower or the group (Gilbert, 2004; Harrison & Treagust, 2000). For chemical educators, mental models are important constructs to identify because they convey how people understand and represent chemical phenomena (Akaygun & Jones, 2014, p.785). Furthermore representations in textbooks may be effective through constructing an individual's own mental model. Hence it is important to enable students to face with scientifically correct images in textbooks in order to have correct mental models.

The topics about matter and properties have been taught until primary education and the subjects related with particulate nature of matter haven taught from middle schools in Turkey. The name of unit at third and fourth grade is "Identification of Matter", at fifth grade "Changes of Matter", at sixth grade "Particulate Nature of Matter", at seventh and eighth grade "Structure of Matter and Properties". On the other hand, although students face with the topic for more than half of their primary education duration, the studies show that they still have alternative concepts about the topic (Boz, 2006; Gabel, 1993; Geban & Bayır, 2000; Griffiths & Preston, 1992; Harrison & Treagust, 1996; Kavak, 2007; Nakhleh & Samarapungavan, 1999; Nakhleh, Samarapungavan & Sağlam, 2005; Ingham & Gilbert, 1991; Tezcan & Salmaz, 2005). In literature, researchers offer some sources for alternative concepts about PNM. For example, Özmen and Kenan (2007) say that due to including too much abstract concepts in the topic, students have many alternative concepts. In another study, Bunce and Gabel (2002) say that teaching chemistry usually based on symbolic representations causes students to have difficulty when they face the interaction of atoms, molecules and ions. Adadan, Irving and Trundle (2009) advocates that students have trouble about associating background of daily events with PNM. In addition, another similar conclusion was done by Özalp and Kahveci (2011). They states that students may interpret PNM with respect to physical states of the matter. This may be one of the reasons for students to have alternative concepts about PNM. Furthermore, the acquisition of knowledge by students without a clear understanding may be attributed to the confusion caused in having to deal simultaneously with the macroscopic, submicroscopic and symbolic worlds of chemistry (Chandrasegaran, Treagust & Mocerino, 2007). There are many studies in literature (Margel, Eylon & Scherz, 2008; Nyachwaya et al., 2011; Özmen, 2011; Valanides, 2000; Vermaat, Terlouw & Dijkstra, 2003) which supports the idea that students have difficulty while translating between representation levels. Moreover although many high school teachers are able to translate between representational levels in their courses unconsciously, they do not emphasize on integrating three representation levels (Gabel, 1999). As a consequence of this, students may be unable to see the relation between representational levels despite they may know the chemistry at the three levels (Chandrasegaran, Treagust & Mocerino, 2007). Besides Gabel (1999) advocates that helping students to relate three levels of representing has potential for improving their conceptual understanding. Some other studies (Chittleborough, Treagust & Mocerino, 2005; Dori & Hameiri, 2003; Gabel, 1993; Johnstone, 1993) also advocate that if students be able to translate among three basic representation levels in chemistry, they might be more successful. All these studies support the idea that emphasizing the transition among representational levels in lectures and the distribution of them on textbooks has crucial roles. On the other hand, there are the most number of representations in textbooks among printed materials (Lee, 2010) and students mostly face with representations via them. For this reason, how inscriptions are deployed in textbooks has an important role in the living experience of students and in their associated appropriation of practices in the course of schooling (Pozzer & Roth, 2003).

Amongst various tools used to represent chemical concepts, visual images have prime importance because chemistry involves the visualization of structures, behaviors and processes (Akaygun & Jones, 2014). On the other side, not only the images (or representations) but also the relation between text and the image (or representation) or caption and the image (or representation) should be accurate in order to prevent confusion in students' minds. Because of the fact that a photograph can give rise to several possible meanings to the reader(s), authors use captions and embed this photograph/caption combination in still further main text that together constrain the meaning a reader can make (Pozzer & Roth, 2003). Hence, on one hand an image that has not been well designed may give rise to wrong conceptual understanding and on the other hand, a lack of knowledge in the main text or caption may prevent the interpretation of an image (Pinto & Ametller, 2002). Within all these respects, this study has crucial role in educational context since it does not only examine the number of images about PNM that are used in middle school science textbooks which are widely used by both teachers and students but also investigates the distributions of representation types about PNM and whether the relations between images and main texts are appropriate for the readers' understanding and also analyzes the captions whether they are suitable or problematic for the images. Because the use of visual language (through texts, schemas, graphs, drawings, etc.) is one of the easier and efficient way to communicate information in classrooms (Pinto, 2002), examination of visuals in textbooks is important. In other respect, teaching and learning is a series of complex activities that are a strong challenge for anyone hoping to generate any kind of generalized knowledge about what makes for effective chemistry teaching (Taber, 2012, p.398). For this reason, each study is a kind of contributor to chemistry education. In addition, studies about textbook analyses address researchers to conduct similar research designs in their own countries and to compare and contrast their findings with international studies' results.

Purpose of the Study and Research Questions

The units about matter and its properties have been teaching from third grade to the university level in Turkey (MEB, 2013). The topic about PNM, firstly, is taught at sixth grade. With respect to the science curriculum developed by Ministry of National Education in 2013, there are 27 objectives about the topic in sixth grade curriculum. The number of objectives about the topic increases for seventh grade. There are totally 46 objectives for the unit about PNM in seventh grade curriculum. In eighth grade, the objectives about matter and its properties decrease. There are 17 objectives in eighth grade curriculum. Seventh grade curriculum is more intensive than the others. Students face much more concepts about PNM at this grade. The reason for decreasing in number of objectives about PNM at eighth grade curriculum might be the topic branches into new related topics and these related topics compose new units.

The purpose of study is to examine images about PNM in middle school science textbook in terms of representational levels, relatedness to text and properties of captions. Within this scope, the research questions were determined as;

1) How does the number of images about PNM in middle school science textbooks change with respect to grade levels?
2) What types of images about PNM are there in middle school science textbooks and how do they change by grade levels?
3) About the images of PNM used in middle school science textbooks;
    a. What is the degree of relatedness to texts?
    b. How are the properties of captions?

Data Collection

Qualitative research methods were used in the study. The aim of qualitative research is not verification of a predetermined idea but discovery that leads to new insights (Sherman & Webb, 1988). In qualitative research methods, although data is usually gathered by interviews or observations, document analysis is also another type of data collection (Savenye & Robinson, 2004). In the current study, the images about PNM in science textbooks will be evaluated by using document analysis.

The researchers took consider three main criteria while choosing the middle school science textbooks. These are

- Middle school science textbook must be approved by Ministry of National Education,
- Middle school science textbook must be currently used,
- Middle school science textbooks must be widely used.

Within these considerations, three sixth grade science textbooks, three seventh grade science textbooks and two eighth grade science textbooks used in 2013-2014 school year were selected. Researchers collected totally eight science textbooks and reached them through public schools or publishers. All the images, out of from activity parts and assessment parts, in the units about PNM in Turkish middle school science textbooks were counted as visuals (See Appendix 1). Excluding the images in the activity parts and assessment parts of units may be considered as limitation of current study.

Data Analysis

Firstly, the units for each grade level were determined. The selected unit for sixth grade science textbooks was "Particulate Nature of Matter" and for the seventh and eighth grade, the titles of units were "Matter and Its Properties". Then the rubric, which was developed by Gkitzia, Salta and Tzougraki (2011), was used to evaluate the images in selected units from middle school science textbooks (See more examples in Appendix 2). The aim of instrument is to assess chemical representations and their properties with respect to several criteria. These are types of representations, relatedness to text and properties of captions.

1st Criteria (C1): Types of Representation

It examines the images about PNM in middle school science textbooks morphologically. It categorizes the images into macroscopic representation, sub-microscopic representation, symbolic representation, multiple representation, hybrid representation and mixed representation.

The images, which represent tangible, observable and touchable objects or concepts, are kind of macroscopic representations. Secondly, the images that are used to represent for atomic and molecular structures, ions, electrons and so on, which are not possible to be observed by a naked eye, are type of sub-microscopic representations. The next type of representations is symbolic one, which is used for to represent elements' symbols, formulas of compounds, the signs of protons and electrons. The other type of representations is multiple representations in which two or three different representation types are used together by reuniting two or more representations to indicate a concept or process. This kind of representation type generally indicates complementary roles of multiple representations. The fifth type of representations is hybrid representations. There is a great similarity between multiple and hybrid representations. The certain difference between them is that multiple representations show a phenomenon at two or three levels by combining two or three representations, while hybrid representations combine characteristics of two or three levels embedded to form one representation (Gkitzia, Salta & Tzougraki, 2011, p.8). The last type of representation is mixed representations which occur by using another visual depiction together with chemical representations (macroscopic, sub-microscopic, and symbolic) or using images analogically (Gkitzia, Salta & Tzougraki, 2011). In another study, Ainsworth, Bibby and Wood (1997) define mixed representations as a bridge to understand symbolic representations by using pictorial images.

2nd Criteria (C2): Relatedness to Text

Relatedness to text criteria is generally important for constraining interpretation because it might be difficult for readers if it is written on a textbook 'rabbit is beside to carrot'. It is hard to understand where the rabbit is. Is it on the right side or left side of carrot? The criterion investigates not only the relationship between images and texts but also analyzes whether there is any statement for students in order to direct them to the representations. Important concepts and information should be placed in the main text, with the appropriate reference to the inscription that would help the reader make sense of the phenomenon under scrutiny (Pozzer & Roth, 2003). Cheng and Gilbert (2015) advocates that students actively construct meaning when they read texts and diagrams. There are five sub-categories in the criteria. These are i) completely related and linked, ii) completely related and unlinked iii) partially related and linked, iv) partially related and unlinked, v) unrelated. In order to analyze the relation between the text and the image, researchers read all passages related to all images by one by. They examined the content of texts and discussed to determine whether it is related with the images or not. In the second step, they investigated phrases like 'as shown the photograph', 'the (water) molecule model given at below', 'the image shows that' or 'as shown in the figure' in order to specify whether there is a link in the text so as to direct students' attentions to the image.

3rd Criteria (C3): Properties of Captions

The criterion probes captions with respect to they are suitable or problematic for the representations. Properties of captions were categorized into three sub-categories which are suitable captions, problematic captions and no caption. The caption is an essential part of the inscription that tells the reader what look for in the photograph and therefore how to read and understand it (Pozzer & Roth, 2003). The other main role of using photograph-caption combination is to limit the meaning of an image for readers (Pozzer & Roth, 2003). It can be said that captions carry both complementary and constraining interpretation roles of multiple representations. They label what the image shows or represents. This can be complementary function of it since it helps the readers what the image consists. In addition, captions describe the image verbally. It is similar to relatedness to text criterion. It helps learners to make correct interpretations about the image. In other words, captions are crucial since appropriate ones make an image's understanding easier (Gkitzia, Salta & Tzougraki, 2011). That is they complete each other with images. We have labeled the image with suitable caption if the caption explains what the visual represents exactly. On the other hand, we have titled the image with problematic caption if the caption does not describe what the visual represents accurately. In the third sub-category, we have tagged the image if it has no caption.

For the next step, reliability values for the study were calculated. In this study, reliability was provided by researcher diversity which is a type of diversity techniques for qualitative researches. Three different researchers analyzed the images with respect to the scale independently and their results were compared by computing Krippendorff's Alpha reliability. The results are shown at the Table 1.

Criteria	***Krippendorff's Alpha Coefficient***
Types of Representations	0.81
Relatedness to Text	0.72
Properties of Captions	0.75

Table 1: Reliability value for each criterion

Findings

Totally 825 images were identified in related units at middle school science textbooks. These images were analyzed with considering the criteria and the results are shown with respect to research questions.

1) How does the number of images about PNM in middle school science textbooks change with respect to grade levels?

The number of images about PNM in middle school science textbooks is given on Figure 1. The most frequent images were used at seventh grade science textbooks (50%; 416 representations). It decreases for the sixth grade science textbooks (31%; 252 representations) and reaches the lowest level on eighth grade science textbooks (19%; 157

representations).Moreover, it is expected that the change of the number of images about PNM in middle school science textbooks are proportionally related to the number of objectives related to PNM in different grade levels. The highest number of images about PNM in seventh grade science textbooks (416) is proportional to the objectives of the PNM (46) at that grade level. Similarly, the numbers of images about PNM in sixth and eighth grade levels (252 and 157 respectively) are proportional to the objectives of the PNM (27 and 17 respectively) at those grade levels.

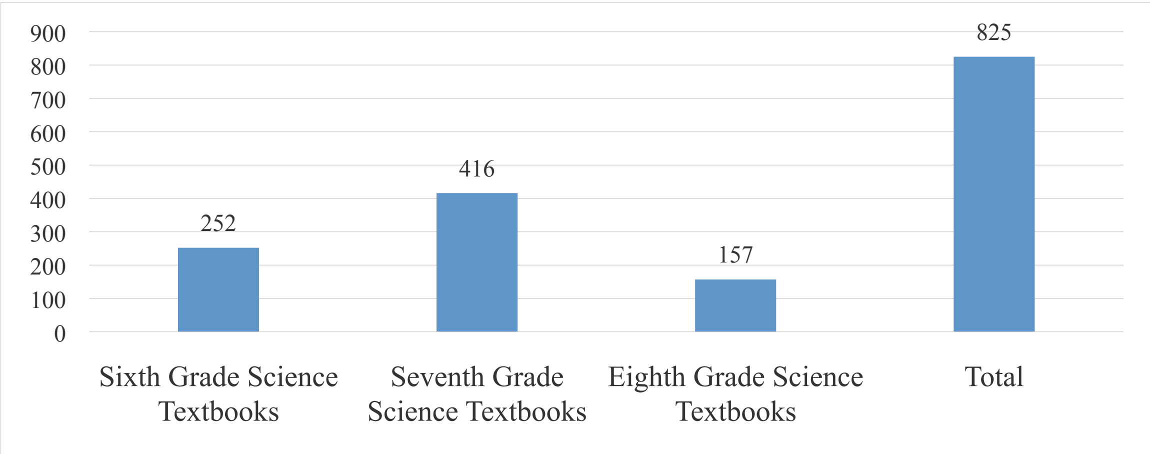


Figure 1: Total Number of Images and Distribution of Them with Respect to Grade Levels

2) What types of images about PNM in middle school science textbooks and how do they change by grade levels?

Figure 2 shows that the dispersion of representation types of images about the PNM. According to Figure 2, the most common representation type of images about the PNM at Turkish middle school science textbooks is macroscopic representations (36%). The next prevalent representation kinds are sub-microscopic (23%) and multiple representations (23%). Symbolic representations have 11% prevalence among all representation types. In other words, there is just one symbolic representation among 10 images. The fewest used representation types in all grade science textbooks are mixed (4%) and hybrid (3%) representations.

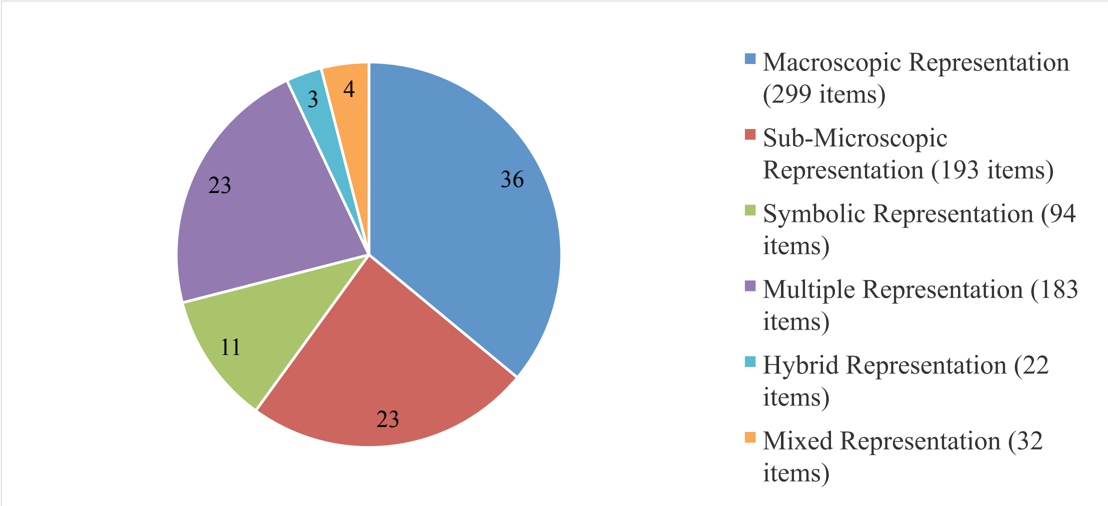


Figure 2: Distribution of Representation Types (%) for All Middle School Science Textbooks

Figure 3 indicates the dispersion of representation types in middle school science textbooks with respect to grade levels.

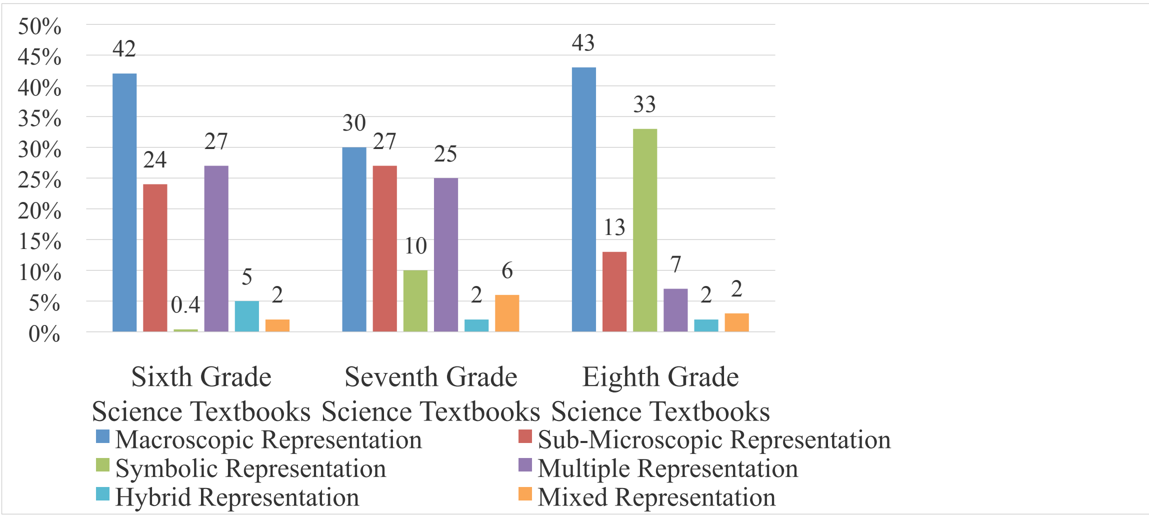


Figure 3: Distribution of Representation Types (%) in Middle School Science Textbooks with Respect to Grade Levels

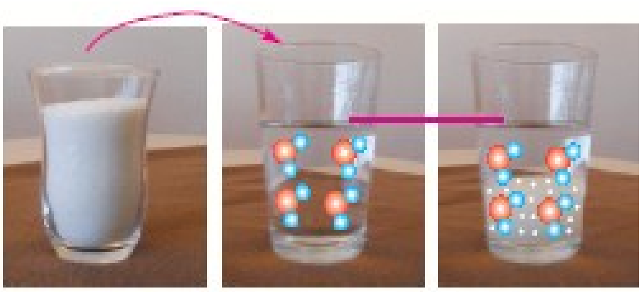
It is shown on the Figure 3 that macroscopic representations have similar usage prevalence in the sixth and eighth grade Turkish middle school science textbooks (respectively 42%; 43%). One of the significant findings is that the ratio of macroscopic representations decreases to 30% in the seventh grade science textbooks although the number of objectives (46) about the PNM was the highest at this grade level whereas the number of macroscopic images in eight grade science textbooks increased even though the number of objectives (17) about the PNM was the lowest at this grade level.

On the other hand, sub-microscopic representations have approximate usage ratio for the sixth and seventh grade Turkish middle school science textbooks (respectively 24%; 27%). It also has low usage ratio in eighth grade science textbooks (13%). It is about half of the ones in the sixth and seventh grade Turkish middle school science textbooks (13%). While increasing in grade levels, it was expected that sub-microscopic images could be higher than other lower grades' science textbooks. Moreover, the gap between the percentage of macroscopic images (43%) and submicroscopic images (13%) was large in the eighth grade science textbooks.

In relation to Figure 3, the percentage of symbolic representations increased from 0.4% in sixth grade science textbooks to 10% in seventh grade science textbooks and reached at most in eighth grade science textbooks (33%). This increase in percentage of symbolic representation by grade level is an expected outcome of the current study since students has learned more symbols and formulas by having been introduced more topics such as chemical reactions and bonding in the eighth grade. However, there was a huge gap between the percentages of symbolic representations (33%) and submicroscopic representations (13%) in the eighth grade textbooks. On the other side, the percentage of symbolic representations in seventh grade science textbooks could be higher since there are topics like elements and their symbols and compounds in the curriculum. Moreover, there was a sharp increase in the use of symbolic representations from 10% in the seventh grade science textbooks to 33% in the eighth grade science textbooks.

The occurrence of multiple representations decreased from 27% in sixth grade science textbooks to 25% in seventh grade science textbooks. These conclusions show that almost one of four images are multiple representations in sixth and seventh grade science textbooks. Interestingly, it has just 7% usage prevalence in eighth grade science textbooks. This is also a surprising result because there is a sharp drop from 25% to 7% which is a very low value for multiple representations in eight grade science textbooks.

Hybrid and mixed representations have the fewest usage levels for all middle school grades' science textbooks. Hybrid representations decreased from 5% in sixth grade science textbooks to 2% in seventh and eighth grade science textbooks. Low percentage of hybrid representations in middle school science textbooks could seem to be an affirmative outcome because they may have high possibility to cause alternative concepts for students. Figure 4 can be given as an example for hybrid representation from the sixth grade science textbook. The image represents water as both macroscopically and sub-microscopically without any sign showing differences between two types of representations in an image that may lead students to misinterpret sizes and distances between water and sugar molecules.



Sugar Water Sugar Water

Bee Hive

Figure 5: An example image for mixed representation from six grade science textbook

Figure 4: An example image for hybrid representation from six grade science textbook

Likewise, the existence of mixed representations decreased from 6% in seventh grade science textbooks to 2% in sixth and eighth grade science textbooks. Figure 5 can be given as an example for mixed representations. The image indicates that bees' entrance and outgoings without constraint. This situation represents how gas molecules move freely in an analogical perspective. However, mixed representations should be clearly linked with the text to show students how these representations with a given analogy related to each other.

3) About the images about PNM used in middle school science textbooks;
   a. What is the degree of relatedness to texts?

Table 2 shows that the distribution of relatedness to texts with respect to grade levels. It is found that four of 10 images are completely related and linked. In addition, whereas one third of images are completely related, they are unlinked with texts. Moreover, 19% of images are found partially related with texts. In other words, one fifth of images used in units about PNM are partially related with texts. Lastly, 4% of images are unrelated.

In the sixth grade textbooks, a total of 53% of the images were unlinked with the text either completely related (30%) or partially related (23%). In the seventh and eighth grade textbooks, almost half of the images (48% and 47% respectively) were unlinked with the text either completely related (40%, and 24%) or partially related (8%, and 23%).

	Completely Related and Linked		**Completely Related and Unlinked**		**Partially Related and Linked**		**Partially Related and Unlinked**		**Unrelated**	
	f	%	*f*	%	*f*	%	*f*	%	*f*	%
Sixth Grade	95	38	76	30	18	7	59	23	5	1
Seventh Grade	195	47	167	40	9	2	33	8	12	3
Eighth Grade	63	40	38	24	8	5	36	23	12	7
Total	353	43	281	34	35	4	128	15	29	4

Table 2: Distribution of Images Relatedness of Texts with Respect to Grade Levels

Completely related and linked images are at the highest ratio (47%) in seventh grade science textbooks. They decreased to 40% in eighth grade and 38% in sixth grade science textbooks. Indeed, it was expected that the relation between text and image could be the highest in sixth grade science textbooks because students firstly face with PNM and related concepts. In addition, the images, which are completely related but have no link in texts, are again at most in seventh grade science textbooks. It decreased to 30% in sixth grade science textbooks and 24% in eighth grade science textbooks. Such kind of text-image combination could be at most in eight grade science textbooks since students' metacognition levels biologically higher at this grade than sixth and seventh grade students.

Partially related and linked images increased from 2% in seventh grade science textbooks to 5% in eighth grade and 7% in sixth grade science textbooks. Similarly, the usage of partially related and unlinked images increased from 8% in seventh grade science textbooks to 23% in sixth and eighth grade science textbooks.

Finally, the unrelated images decreased from 7% in eighth grade science textbooks to 3% in seventh grade and 1% in sixth grade science textbooks.

b. How are the properties of captions?

Properties of captions were categorized into three different sub-titles which are suitable, problematic and no caption. Figure 4 summaries the distribution of properties of captions with respect to grade levels.

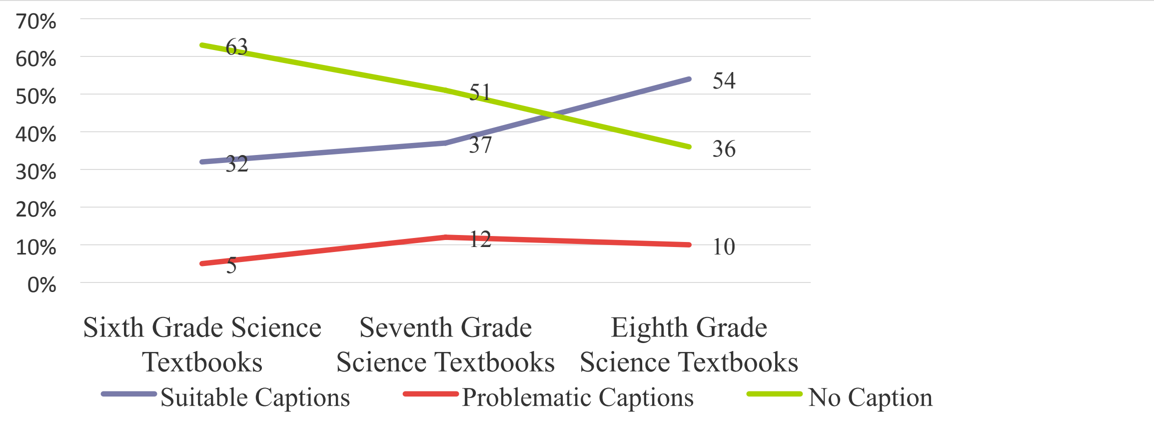


Figure 4: Distribution of Appropriateness of Captions (%) with Respect to Grade Levels

It is reached that the visuals, which are about PNM in middle school science textbooks, in eighth grade science textbooks have suitable captions at most (54%). It decreased to 37% in seventh grade science textbooks and reached it's the lowest ratio for the representations in sixth grade science textbooks (32%). It is interesting that the ratio of suitable caption in middle school science textbooks decreases from eight grade to sixth grade.

It is one of remarkable results that more than half of the images (63%) in sixth grade science textbooks have no caption. It decreased to 51% in seventh grade science textbooks and 36% in eighth grade science textbooks. This result may show that students have trouble to understand the messages carried by the images.

For the images with problematic captions, it increased from 5% in sixth grade science textbooks to 10% in eighth grade science textbooks and 12% in seventh grade science textbooks.

Discussion

Knowing that teaching and learning strategies depend heavily on textbooks, researchers should more carefully investigate the pedagogical potential of photographs and how students and teachers make use of these visual resources to achieve and help others to achieve understanding (Pozzer Ardenghi & Roth, 2004). In the study, the research questions are about amount of images, types of representations, captions' properties and relation between texts and images about PNM in Turkish middle school science textbooks.

The findings reveal that macroscopic representations are used widely in middle school science textbooks. This consequence emphasizes that PNM is usually taught by concrete concepts in science textbooks. It is indispensable fact that macroscopic representations have important roles through teaching process especially introducing new concepts for students (Johnstone, 2007). Also students' interests are much more while teaching with this type of representations (Harrison & Treagust, 2003). On the other hand, due to the fact that the topic includes a lot of abstract concepts, representing the topic with high incidence of macroscopic images in science textbooks is a contradictory result. It is also interesting that the most common representation type is macroscopic ones at eighth grade science textbooks because it is usual that increasing in grade levels should be parallel to increment in abstract concepts. The characteristics of the images needed are very different according to the students' age or achievement level (Pinto, 2002). Similar finding was also found by Dimopoulos, Koulaidis and Sklaveniti (2003). They analyzed textbooks and scientific articles published by newspapers and concluded that visuals on these materials are mainly real copies of themselves.

A significant finding of the study indicates the low use of sub-microscopic representations in middle school science textbooks. Surprisingly, this kind of representation is at the lowest level at eighth grade science textbooks. Just one of 10 images is at sub-microscopic level at eighth grade science textbooks. It is also similar for sixth and seventh grade science textbooks since there are merely two or three out of 10 visuals are at sub-microscopic level. Owing to the fact that sub-microscopic level plays an important role in helping students to develop a mental image of the sub-micro level which is vital because chemical explanations nearly always depend on the sub-micro level (Chittleborough & Treagust, 2007; Davidowitz & Chittleborough, 2009) and PNM covers many intangible concepts, it was supposed that there could be more sub-microscopic representations at middle school science textbooks.

Submicroscopic entities are real but they are too small to be observed, so chemists describe their characteristics and behavior by using symbolic representations to construct mental images (Treagust, Chittleborough & Maimala, 2003). They are at most in eighth grade science textbooks which was an expected outcome because eighth grade curriculum requires using them frequently. Nevertheless, although seventh grade curriculum involves concepts like atom, molecule and compound, symbolic representations which means that chemical expression of these, were used just for one of 10 images. The study done by Bunce and Gabel (2002) also support the idea that chemistry education at schools does not emphasize on submicroscopic level of chemical concepts. Nonetheless, not understanding the meaning of the symbolic languages makes it difficult to understand the concepts or ideas (Taber, 2009). In order to deal with such situation, symbolic representations could be used much more in the units about PNM at seventh grade science textbooks. There is just one symbolic representation in sixth grade science textbooks that may be due to the fact that sixth grade curriculum does not cover the topics such as elements, compounds and chemical reactions which includes highly intensive symbolic images.

There is notable finding about multiple representations which means that exploiting combinations of representations. It has the lowest prevalence at eighth grade science textbooks. This type of representation is more than three times in both sixth and seventh grade science textbooks. This result conflicts with the studies (Chittleborough, Treagust & Mocerino, 2005; Gabel, 1993) which advocate that ensuring transition between representation levels increases the achievement in chemistry education. Ainsworth (1999) also claims that learners are less likely to be exposed by the strengths and weakness of any single one, when they take advantage of multiple representations.

The classification of representations among multiple, hybrid and mixed in textbooks is significant since each of them has different purposes and functions for teachers' utilization and student learning so they have both strengths and weaknesses. Therefore, educators especially teachers who utilize textbooks most should carefully select and use images in their teaching based on considering possible weaknesses as well as benefits. For example, in hybrid representations, two representations are embedded in an image without any guide to help readers understand differences between representations. As a result, hybrid representations have potential to cause alternative concepts. In other respect, Justi and Gilbert (1999) advocate that using hybrid models in teaching means that scientific knowledge is context independent and this leads students to have alternative conceptions in their mental models (p. 173).

Similar to hybrid representations, mixed representations are occasionally used in middle school science textbooks. Mixed representations may enable students to connect process or concept with an event from daily life which may give rise to meaningful and deeper learning. Nevertheless, this can only occur if students see how the two representations relate to each other (Ainsworth, Bibby & Wood, 1997, p.100). Mixed representations also should carefully be used for teachers and textbooks authors due to their complex in an analogic perspective. Although analogies can be influential teaching tools, it is agreed that not all analogies are good and that not all good analogies are useful to all students (Orgill & Bodner, 2004). Analogies have been called 'double-edged swords' since the appropriate knowledge they can make is often associated with alternative conceptions (Bellocchi and Ritchie, 2011; Taber, 2005; Nakiboğlu & Taber, 2013). Moreover, the pedagogical implications of multiple representations suggest that teachers cannot simultaneously present different types of representations in teaching difficult science concepts. Otherwise, students would become overloaded with information and be unable to see the connections between the levels (Treagust, 2007). In addition, there are studies (e.g. Ainsworth, Wood & Bibby, 1996) in the literature which show that students have low performance and understanding when they used combination of pictorial and mathematical representations as mixed instead of using pictorial and symbolic representations separately.

Another crucial result is about the relation between images and texts. Paivio (1986) advocates that information can be recalled and manipulated more easily if it is encoded in verbal and visual systems. It means that students might be exposed to meaningful and deeper learning if their cognitive systems be stimulated by two stimuli. In other words, just texts or just images are not enough for meaningful understanding. When these two representation types are presented together, interpretation of ambiguous representation (e.g. just text) may be constrained by the specific representation (e.g. an image) independently of issues of familiarity or experience (Ainsworth, 1999, p.140). In the current study, it was found that just nearly four images about PNM is completely related and linked with texts. Pozzer Ardenghi and Roth (2004) state that main texts are certainly an important resource in helping the readers to interpret the photographs. It would be difficult for students to have correct interpretations about images if it has no relation and is not linked in the main text. Totally almost half of the images about PNM in Turkish middle school science textbooks are unlinked in main texts. Furthermore, one fifth of images are partially related with the texts. Pinto and Ametller (2002) state that not only an image which is not well designed but also a lack of knowledge in the main text make the image's understanding difficult. Based on the findings of the current study, the coherence between images about PNM in Turkish middle school science textbooks and texts is weak.

Finally, captions are also one of the vital components of images that tell the reader what look for in the photograph and therefore how to read and understand it (Pozzer & Roth, 2003). Whereas surface features of representations clarify the labeled part, captions explain the entire representation mission. For the images about PNM in Turkish middle school science textbooks, more than half of them have no caption. It is also noteworthy consequence that images with no caption are at most in sixth grade science textbooks despite students face with the topic first time at this grade. Captions can be helpful, especially in the case of unfamiliar concepts; with no caption, they would remain mystery (Woodward, 1993). While increasing in grade levels, the numbers of visuals with no caption decreases. Approximately four of 10 representations in middle school science textbooks have suitable captions. Furthermore, even some visuals have captions; they are problematic which means that caption does not explain what the representation wants to teach. Overall, these results emphasize that captions are not used appropriately for teaching PNM concepts at Turkish middle school science textbooks.

Suggestions

Findings of the current study provide some suggestions for science teachers, textbook publishers and researchers.

First of all, owing to the fact that science teachers have vital role through teaching chemistry concepts, several suggestions can be offered. Since students have difficulty when they face with the concept at different representational levels (Chittleborough & Treagust, 2008; Nyachwaya et al., 2011), science teachers should emphasize on representation of the concept at different levels. For example, teachers may have students to focus on the similarities and differences among representations of ice, water and water vapor molecules in science textbooks. Within this respect, students should be able to understand the concept at different representational levels. In order to achieve this, teachers may use images in textbooks, conceptual models or technology enhanced teaching tools (e.g. computer based models). Furthermore teachers may provide other sources such as scientific journals, internet and so on for students, to enable students so as to see different images and different types of representations of same concept. It is also important to notify that multiple representations decrease with respect to grade levels. Nevertheless, it is expected to increasing in number of multiple representations according to grade levels because in upper classes, there are objectives about PNM which requires combination of different representational levels. Within this respect, it is important for teachers to mention multiple representations especially for upper classes. If the images have no caption or lack of relation with texts in order to be sure about students' understandings through images, teachers may want their students to explain the images or can create classroom discussions about the topic through the images. For example teachers may present the image with no caption or/and lack of relation with text and enable students to say their views about the image and try to reveal what they understand from the image.

Secondly, textbook authors and publishers have important responsibilities through textbooks writing process. In Turkey, the Head Council of Education and Morality determines the textbooks which are used at schools. The members of this council should take consider carefully about how images have been used in textbooks as a part of evaluation criteria. The results of current study indicate that many visuals have been used in Turkish middle school science textbooks. The course books which covers a lot of images does not mean that it has a high quality. For this reason, while determining images in textbooks, textbook authors should consider about the mission of representations. Instead of using too much visual to make the textbooks colorful and attractive, authors might try to use images from different representation levels and directly related with the topic and text which also can be remarkable for students. Moreover, there are macroscopic representations at most in Turkish middle school science textbooks but PNM covers a lot of abstract concepts. Therefore, textbook authors should consider about appropriateness between concepts and images. For example ball and stick models might be used while teaching atom or molecule concepts in textbooks, instead of using the photo of element itself. Same concept or event should be shown by images from different representational levels. In this way, students might be able to see the same concept in different levels. Another suggestion for textbook authors and publishers may be about the relation between text and image in textbooks and images' captions. Because of the fact that limited images about PNM in Turkish middle school science textbooks are completely related and linked, understanding of images' meanings may be trouble for students. It is also important consequence that almost half of images have no caption. If the images have no caption, it is difficult to understand what the image involve and what the aim of it. Thus textbook authors should be careful about using suitable captions for images in textbooks.

Thirdly, the suggestions would be offered for researchers which are the limitations of current study. For instance, how much of these images and how often they have been using by teachers in their classes can be investigated. Moreover further research can be done for how students interpret those images in science classroom. In order respect, similar textbook analysis may be done for different topics in order to reveal how multiple representations are used in science textbooks. Chemical reactions and bonding, solutions and acid and base are possible topics from chemistry education.

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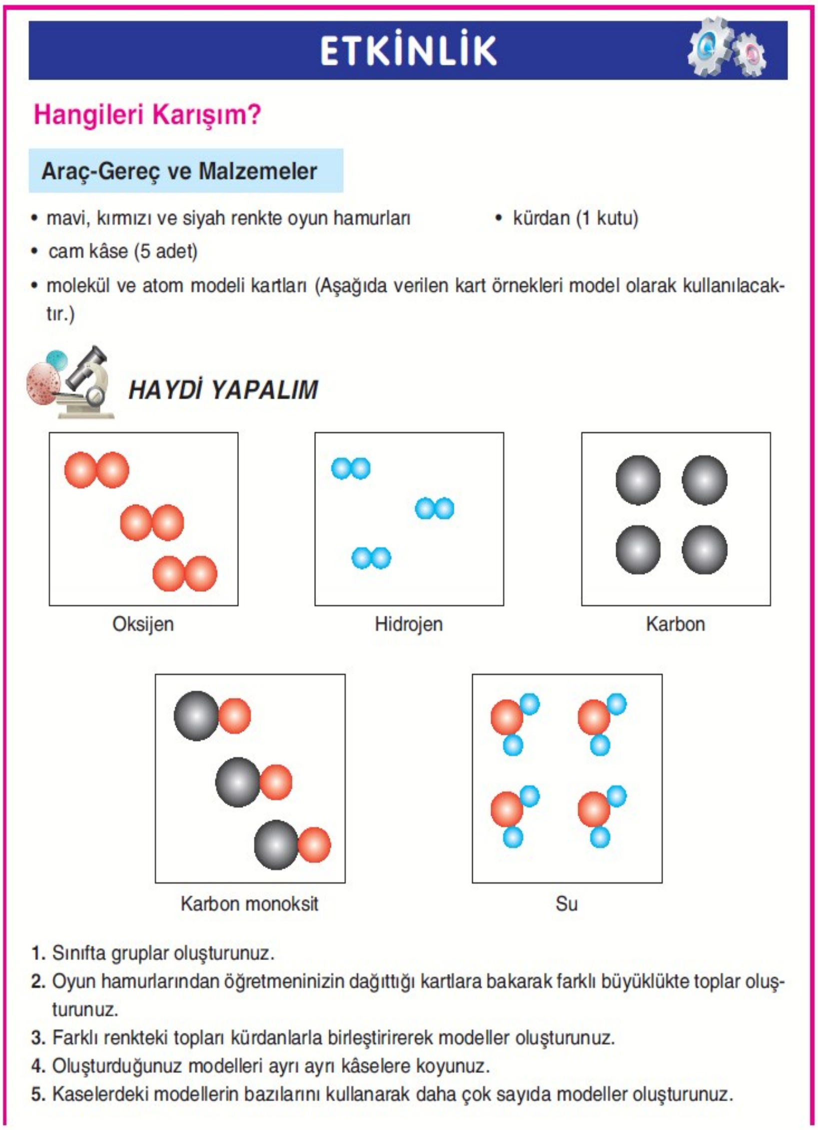
Appendix 1



ETKİNLİK

Hangileri Karışım?

Araç-Gereç ve Malzemeler

- mavi, kırmızı ve siyah renkte oyun hamurları
- kürdan (1 kutu)
- cam kâse (5 adet)
- molekül ve atom modeli kartları (Aşağıda verilen kart örnekleri model olarak kullanılacaktır.)

HAYDİ YAPALIM

Oksijen

Hidrojen

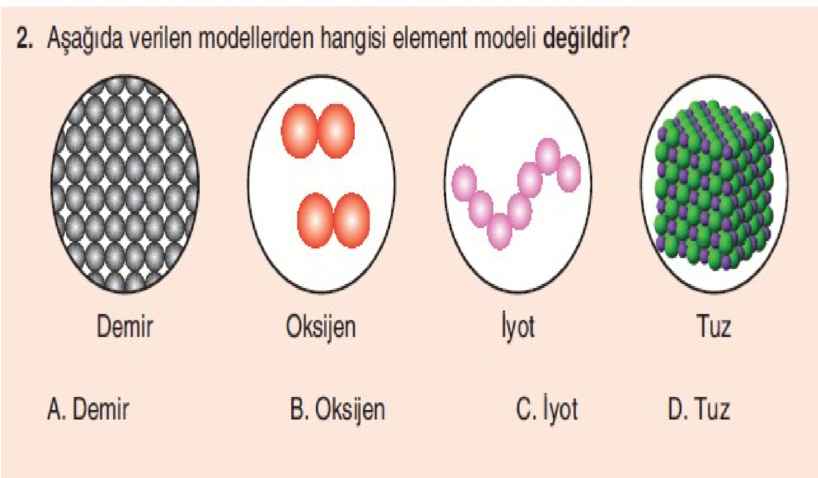
Karbon

Karbon monoksit

Su

1. Sınıfta gruplar oluşturunuz.
2. Oyun hamurlarından öğretmeninizin dağıttığı kartlara bakarak farklı büyüklükte toplar oluşturunuz.
3. Farklı renkteki topları kürdanlarla birleştirirerek modeller oluşturunuz.
4. Oluşturduğunuz modelleri ayrı ayrı kâselere koyunuz.
5. Kaselerdeki modellerin bazılarını kullanarak daha çok sayıda modeller oluşturunuz.

This page was taken from sixth grade science textbooks and the images on this were not evaluated in the study since they are in the activity part of unit.



2. Aşağıda verilen modellerden hangisi element modeli **değildir?**

Demir Oksijen İyot Tuz

A. Demir B. Oksijen C. İyot D. Tuz

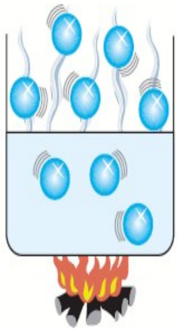
This page was taken from sixth grade science textbooks and the images on this page were not also evaluated in the study since they are in the assessment part of unit.

Maddeleri oluşturan tanecikler titreşim hareketi yapar. Titreşim hareketi, taneciklerin bulundukları yerde öne arkaya, sağa sola, yukarı aşağı yaptığı hareketlerdir. Ayrıca sıvı ve gaz maddeler titreşim hareketinin yanı sıra öteleme hareketi de yaparlar. Öteleme hareketi, taneciklerin birbiri üzerinden kayarak yaptıkları yer değiştirme hareketidir.

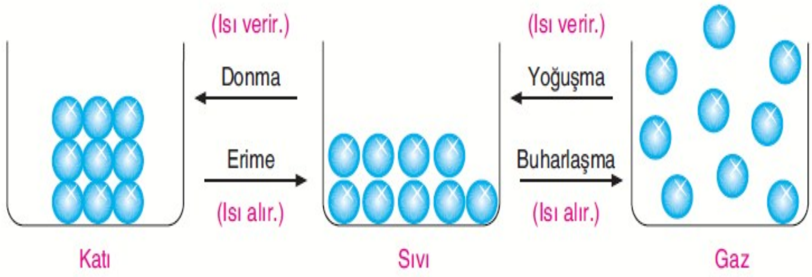
Maddelerin katı, sıvı ve gaz olmak üzere üç hâlde bulunduklarını, ısı alarak ya da vererek bulundukları hâlden başka hâle geçmesine hâl değişimi adı verildiğini daha önce öğrenmiştiniz.

Maddeler hâl değiştirirken taneciklerin hareketinde bir değişiklik olur mu? Katı madde ısı alıp sıvı hâle geçerken tanecikler arasındaki boşluk nasıl değişir? Ya da bunun tam tersi maddeler ısı verirken tanecikleri arasındaki boşluk nasıl değişir?

Aşağıdaki şekilleri inceleyerek bu soruları cevaplamaya çalışınız. Ulaştığınız sonuçları arkadaşlarınızla tartışınız.



This page was taken from sixth grade science textbooks and the images on this page were evaluated in the study since they are in the teaching part of unit.

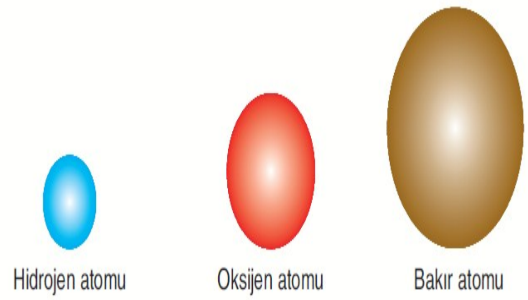


Appendix 2

1st Criteria (C1): Types of Representation

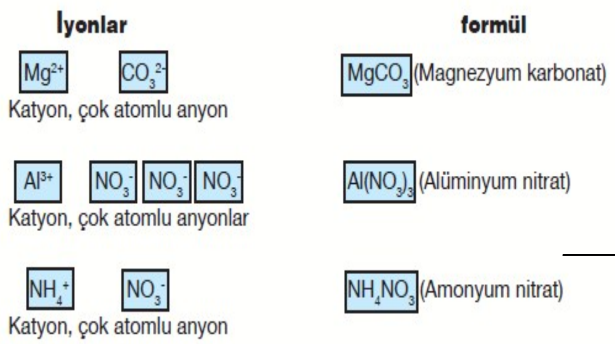
An example for *macroscopic representation*

An ice photo from sixth grade science textbook



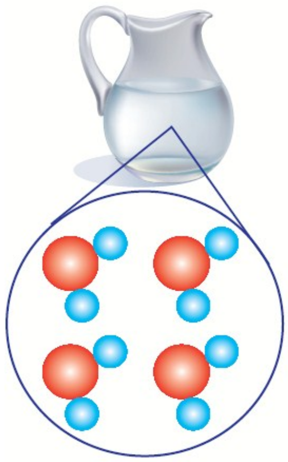
An example for *sub-microscopic representation*

Atom models from sixth grade science textbooks



An example for *symbolic representation*

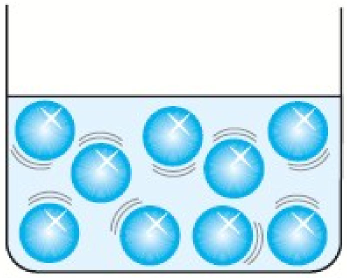
Ions and formulas of compounds from eighth grade science textbook



Water

An image from sixth grade science textbook which indicates water by separate representations as macroscopically and sub-microscopically

An example for *multiple representations*



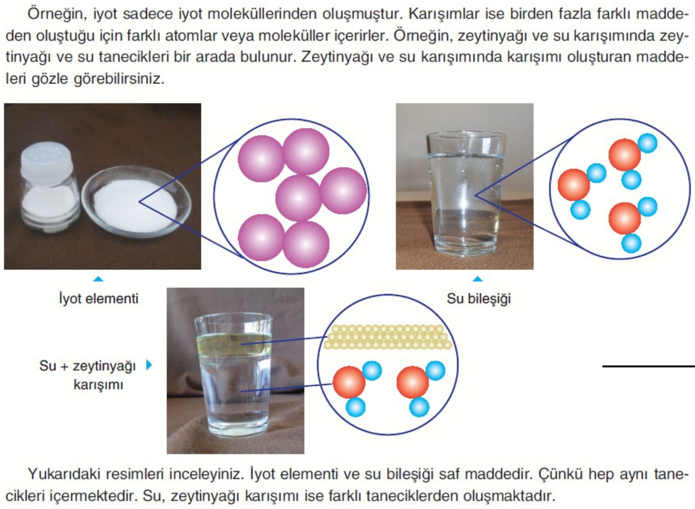
An image from sixth grade science textbook which indicates water and its molecules by unique image which consists of macroscopic and sub-microscopic representations embedded together

An example for *hybrid representation*

An image from sixth grade science textbook which indicates end of a school day and students leave from school. The image is used analogically since each student represent a gas molecule and gas molecules are independent from each other. They can spread easily.

An example for *mixed representation*

2nd Criteria (C2): Relatedness to Text

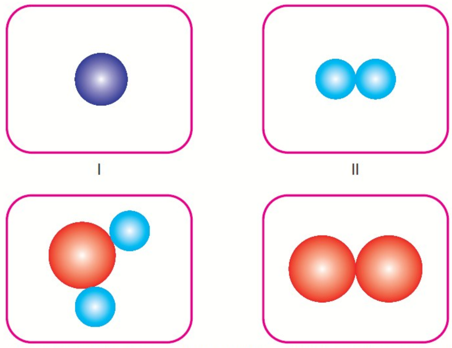


→ An example for *completely related and linked* image

The image is from sixth grade science textbook. The text explains that iodine comprises of iodine molecules and water is composed by water molecules. Two of these are element and compound, respectively. On the other hand, mixtures consist of different atoms and molecules due to they are composed by different matters. Examples are given for element, compound and mixture by images. In addition, the text involves phrases like 'as shown the photograph'.

→ An example for *completely related and unlinked* image

The image is from sixth grade science textbook. The text explains that we can understand gas particles are moveable because smell of meals spreads from kitchen to other rooms at home. The text is completely related with the image but there is no phrase such as 'as shown in the figure' or 'the image shows that'.



Aşağıdaki atom ve molekül modellerini inceleyiniz.

I II

Aynı çeşit kürelerden oluşan model elementi, farklı çeşit kürelerden oluşan model ise bileşikleri temsil etmektedir.

Saf maddeler, elementler ve bileşikler olmak üzere iki grupta incelenir. Resimlerini gördüğünüz hidrojen (II) ve oksijen (IV) molekülleri element molekülüdür. Su molekülü ise bileşik moleküldür. Eğer bir bileşik moleküllerden oluşuyorsa o bileşiğin tüm molekülleri birbirinin aynıdır. Bir molekül kaç tane ve kaç çeşit atoma sahipse o bileşiği oluşturan diğer moleküller de aynı sayı ve çeşitte atom içerir. Örneğin, bir su molekülü iki çeşit atomdan oluşur. Su molekülündeki atom sayısı ise üçtür.

Madde moleküllerden oluşuyorsa moleküler yapıda, atomlardan oluşmuşsa atomik yapıdadır.

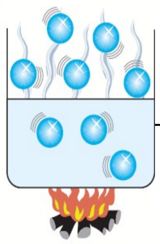
Öyleyse I. kutucuktaki küre, atomik yapılı helyum elementini temsil etmektedir. Diğerleri ise molekül yapılı maddelerin model gösterimidir.

Elementler ve bileşikler saf maddeler olduğundan aynı çeşit taneciklerden oluşur. Bu tanecikler atom ya da moleküldür. Çevremizdeki tüm maddeler sadece elementlerden ve bileşiklerden oluşmamıştır. Günlük hayatta kullandığımız bir çok madde karışım hâlindedir.

İki veya daha fazla madde kendi kimliklerini kaybetmeden bir araya gelerek karışımları oluşturur.

→ An example for *partially related but linked* image

The image is from sixth grade science textbook. The text explains that pure substances are examined into two sub-categories (elements and compounds). As you see hydrogen (II) and oxygen (IV) are molecular elements but water is compound. If a compound is formed by molecules, then each molecule of that compound is the same. Matters also can be formed by atoms. For example, He atom (I) has atomic structure. Namely, the text is not fully explain the image since it is difficult to see which image represent which element or compound. It is relevant to the images and includes link for students to examine the visual.



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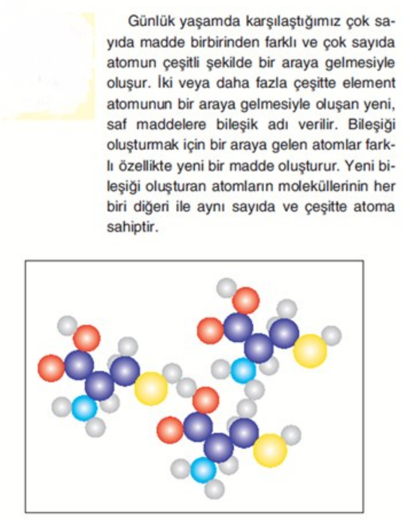
→ An example for *partially related and unlinked* image

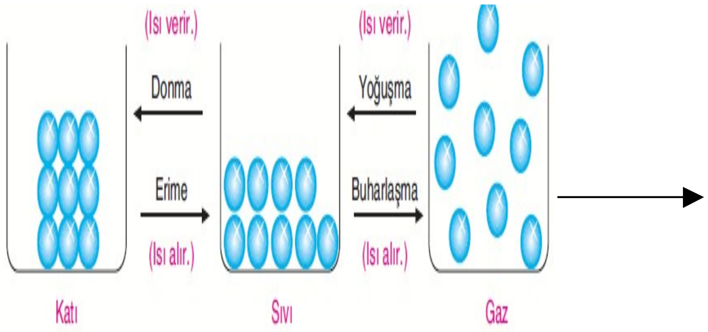
The image is from sixth grade. The text explains about vibrational motion of atoms/molecules in all phases and reciprocating motion of atoms/molecules in liquid and gas phasesmbut there is not much relation between the text and the image. Furthermore, there is no link in the text



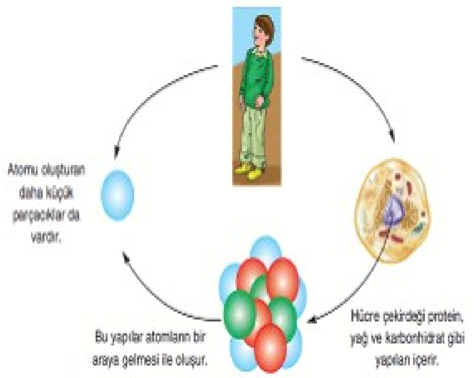
An example for *unrelated* image

The image is from sixth grade science textbook and the text explains that compounds are formed by combination of various atoms. Nonetheless, it does not directly explain the image or it involves no link for students to view the image.

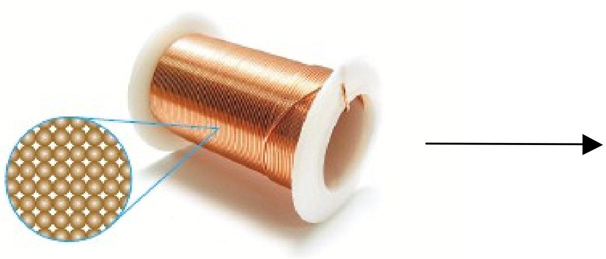
3[rd] *Criteria (C3): Properties of Captions*



An example for the image, taken from sixth grade science textbook, which has suitable caption since it demonstrates exactly transition between phases of matter in sub-microscopic level what the image shows.



An example for the image, taken from sixth grade science textbook, which has problematic captions since it does not enable students to understand the image easily. The captions state that nucleus of a cell includes protein, lipid and carbohydrates which are composed of atoms.



The image was taken from sixth grade science textbook as an example for image with no caption. The image indicates copper wire and its atoms but there is no more explanation about the topic via caption or sub-title.