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Descriptive Analysis of Diagrammatic Representations of Turkish Middle School Science Textbooks

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Abstract: The aim of this study is to examine diagrammatic representations in middle school science textbooks based on diagrammatic typology to find out a general picture of how diagrammatic representations used in science textbooks over fifteen years. Textbooks are an important role in education as primary teaching and learning source. The sample consist of total number of twelve 6th, 7th and 8th grade science textbooks from 2002 to 2017 in Turkey. Textbooks analyzed based on content analysis method. Systematic coding and categorizing of diagrams, photos, charts, graphs, drawings and tables analyzed based on Hegarty, Carpenter and Just's (1991) typology and Khine and Liu's coding scheme. Diagrams coded as Graphical Types including iconic, schematic, charts and graphs, and augmented reality; Gender Representation, Indexing, Captioning and Quality. Finding of the study showed that schematic representations is preferred compared to iconic and charts and graphs. Male representation is highly dominant in all grades of middle school science textbooks.

Keywords: Visual representation, Textbooks, Science education

Introduction

This study aims to find out the distribution pattern of various diagrammatic types being used in the science textbooks published since 2002. Textbooks are important teaching sources which teachers and students have benefit for obtaining knowledge during schooling years (Liu and Khine, 2016; King, 2009, Misulis, 1997, Irez, 2008, Groves, 1995, Devetak and Vogrinc, 2013). Pinto and Ametller (2002) discussed that students assess visual images a part of written text rather than independent way from text. According to Digisi and Willett (1995), textbooks as an important tool for students' science achievement as well as have an effect of students' cognitive and metacognitive skills (Liu and Khine, 2016). 90% of the students learn science from the textbooks (Peacock and Gates, 2000)

Devetak and Vogrinc (2013) suggested that three elements of textbooks are important: general structure, textual material and visual material. General structure includes general information of the textbooks such as number of pages, chapters, length of the chapters etc. Visual aspect of textbooks become even more important in science learning and teaching because according to Kesidou and Roseman (2002) inaccuracies in textbook illustration cause students'' misconceptions and visual representations helps students to develop expert view of conceptual understanding of the subject (Devetak and Vogrinc, 2013)

Form of diagrams, illustrations, drawings, photographs, formulas, graphs and tables are an important part of today's science textbooks (Lee, 2010; Devetak and Vogrinc, 2013). Researcher have been work on visual representation of textbooks. Mainly they research focused on what representations are?, what are they for, how many different types are they, in how many different ways can they be used and what difference does it make whether they are in the mind or on paper?

Half of the page space in science textbooks is dedicated to visual images (Lee, 2010). 85% of those visual images are not related to content (not indexed) (Mayer, 1993). Most of the pictures are iconic (Lee, 2010).

According to Pozzer and Roth (2003) textbook authors preferred to use iconic representations especially to photographs (over 70% of all representations in sample of their study). European and non-European countries textbooks have more texts than images (Liu and Khine, 2016). Iconicity is used high level in modern-day science textbooks (Hegarty, Carpenter, & Just, 1990). According to Kesidou and Roseman (2002) inaccuracies in textbook illustration cause students'' misconceptions (Devetak and Vogrinc, 2013).

Graphical Analysis Protocol (GAP) proposed by Slough and McTigue (2013) is based on four principles: (1) graphics should be considered by form and function, (2) graphics should help a viewer build a mental model of a system, (3) graphics and texts should be physically integrated, (4) graphics and texts should be semantically integrated and discuss three research articles utilizing the GAP instrument for unique science textbooks.

How to Assess Visual Representations

According to Hegarty et al. (1991) diagrams in textbooks are not used in science textbooks randomly by textbook authors instead there should be rules to facilitate students' conceptual change. Liu and Khine (2016) offered modelling which includes three categories:

1. Analogical models: Principle of analogical reasoning is founded in constructivism. According to analogical reasoning students construct his/her cognitive map with associating his/her new information with previous knowledge (Liu and Khine, 2016). Analogical models are symbols, equations and graphs.
2. Diagrams and maps
3. Simulations

Grosslight et al. (1991) suggested three levels of modelling levels. In level 1, students believe that there is a 1:1 correspondence between models and reality (models are toys or small incomplete copies of actual objects); models should be 'right', and they do not search the model's form for ideas or purposes. In level 2, where models remain real world objects or events rather than representations of ideas; and the model's main purpose is communication rather than for exploring ideas. Level 3 includes models should be multiple; are thinking tools; and can be purposefully manipulated by the modeler to suit his/her epistemological needs (Harrison and Treagust, 2000).

Method

Content analysis technique is used to analyze visual representations in textbooks.

Sample

Sample consist of 12 science textbooks published in Turkey from 2002 to 2017. Textbooks for 6-7 and 8 grades. All textbooks were approved by the Ministry of National Education (MoNE). A sample of 6247 visual images (2078 visual image from 6th grade, 2497 visual image from 7th grade and 1697 visual image from 8th grade) in total 2581 pages were collected from the textbooks.

List of the science textbooks are shown below:

- Güngör, B., Dökme, İ., Ülker, S., Yıldıran, F.N., Aydınlı, R. & Baş, B. (2002). İlköğretim Fen Bilgisi 6 Ders Kitabı. Ankara: Milli eğitim Basım Evi.
- Büyük, Ş., Salmaner, V., Baş, Z.B. & Görür, N. (2002). İlköğretim Fen bilgisi 7 Ders Kitabı. Ankara: Milli eğitim Basım Evi.
- Çelik Koyuncu, A., Tiryaki, N., Kavas, B. & Salmaner, V. (2002). İlköğretim Fen bilgisi 8 Ders Kitabı. Ankara: Milli eğitim Basım Evi.
- Taşar, M. F. (Ed.) (2011). İlköğretim Fen ve Teknoloji 6 Ders Kitabı. Ankara: Milli eğitim Basım Evi.
- Boyraz Topaloğlu, Ş. (2012). İlköğretim 7.sınıf Fen ve Teknoloji Ders Kitabı. Ankara: Ekoyay Eğitim yayıncılık.
- Tunç, T., Bakar, E., Başdağ, G., İpek, İ., Bağcı, N., Köroğlu, G. N., Yörük, N. & Keleş, Ö. (2011). İlköğretim Fen ve Teknoloji 8 Ders Kitabı. Ankara: Milli eğitim Basım Evi.
- Öcal, C. (2014). Ortaokul fen bilimleri 6. sınıf. İstanbul: Fenbil Yayıncılık.

- Leblebicioğlu, G. (Ed.). (2014). İlköğretim fen ve teknoloji 7 ders kitabi. MEB.
- Erbaş, K. (2015). İlköğretim Fen ve Teknoloji 8 Ders Kitabı. Ankara: Tuna Matbaacılık Yıldırım Yayınları.
- Gökçe, N. & Işık, N. (2017). Ortaokul Fen Bilimleri 6 Ders Kitabı. Ankara: Tuna Matbaacılık.
- Tuncel, E. (2017). Ortaokul Fen Bilimleri 7 Ders kitabı. Ankara: Tuna Matbaacılık Mevsim Yayıncılık
- Ataş, A. (2017). Ortaokul Fen Bilimleri 8 Ders kitabı. Ankara: Öğün Yayınları
- Urhan, A. (2016). Ortaokul Fen Bilimleri 8 Ders Kitabı. Ankara: Tutku Yayıncılık

Data Analysis

Textbooks analyzed based on diagram coding scheme which was created according to typology proposed by Hegarty, Carpenter & Just (1991) and Khine & Liu (2017). Codes are includes graphical types, gender representation, indexing, captioning, formality of visual image, formulas/equations, function of visual image. A rubric were design based on this coding themes (Table 1)

Table 1. Rubric for coding categories

	Graphical types				**Gender**		**Indexing**		**Captioning**		**Formality of visual images**			**Formulas/ equations**		**Function of visual images**			
Page number	**Iconic**	**schematic**	**Charts/ graphs**	**Augmented reality**	**female**	**male**	**None**	**indexed**	**No caption**	**captioned**	**Conventional**	**Hybrid**	**Realistic**	**Verbal**	**Visual**	**Classificational**	**Analytical**	**Narrative**	**Metaphorical**

Graphical Types

1. Iconic representations are "directly resemble the objects being depicted" (Lee, 2010, p. 5), represent objects concretely and spatially; they commonly take photographs and line drawings of objects, hand-drawing or a photo of a cat (Hegarty, Carpenter & Just, 1990) (Figure 1)
2. Schematic representations are represent abstract concepts and use conventions such as concise notations to describe key relationships or interactions, a chart showing the human digestive system, magnetic fields, Venn diagram (Hegarty, Carpenter & Just, 1990). Diagrams of light rays interacting with matter comprise one of the numerous types of schematic and abstract representations in optical sciences, circuit diagrams, cladograms, and free-body force diagrams (Figure 2).
3. Charts & graphs includes quantitative and numerical data (Hegarty, Carpenter & Just, 1990). Graphic objects and elements that are conventionally used to communicate scientific ideas (Figure 3)
4. Augmented Reality (AR) which images is designed and produced by multimedia technology (Azuma, 1997; Liu and Khine, 2016) (Figure 4)

Figure 1. Iconic image of corns taken from 6th grade textbook (MoNE, 2002, p. 40).

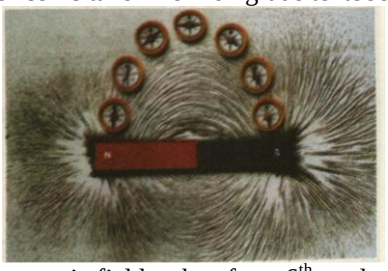

Figure 2. Schematic image of magnetic fields taken from 6th grade textbook (MoNe, 2002, p. 148)

Tür	2n
Kedi	2 x 19
Köpek	2 x 39
Deniz yıldızı	2 x 47
At	2 x 32
İnsan	2 x 23
Molî balığı	2 x 23
Soğan	2 x 8
Güvercin	2 x 8

Figure 3. Charts and graphs taken from 8th grade textbook (MoNe, 2002, p. 112)

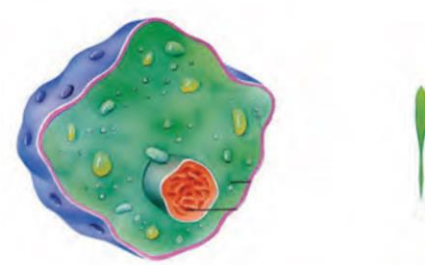

Figure 4. Augmented reality of animal cell taken from 7th grade textbooks (MoNe, 2017, p.16)

Indexing

Indexing analyze based on two categories. First one includes photograph or drawing is not mentioned in the text. The second one includes indexing which has three conditions (1) photograph or drawing is not mentioned in the text, (2) a good textbooks should include relationship between textual and visual material and (3) in a textbook, if visual element is discussed in text than this textbook considered as a good course material (Devetak and Vogrinc, 2013).

Captioning

Captioning analyzed based on no caption and captioned categories. No caption category includes no title or description under graph or drawing. Captioned one has a title or description which is written under graph or drawing.

Formality of Visual Images

Formality of visual images analyzed in three categories.

1. Realistic image: Reality according to human optical perspective including photographs and drawings (Dimopoulos, Koulaidis & Sklaveniti, 2003; Devetak and Vogrinc, 2013).
2. Conventional image: graphs, maps, flowcharts, molecular structures and diagrams (Dimopoulos, Koulaidis & Sklaveniti, 2003; Devetak and Vogrinc, 2013).

3. Hybrids: include both realistic and conventional images (Dimopoulos, Koulaidis & Sklaveniti, 2003; Devetak and Vogrinc, 2013).

Function of Visual Images

1. Classificational: exhibit relationships between people, places and things (Dimopoulos, Koulaidis & Sklaveniti, 2003).
2. Analytical: focus on relationships in object from part to whole structure (Dimopoulos, Koulaidis & Sklaveniti, 2003). .
3. Narrative: in this kind of image include a vector either explicitly or imaginarily (Dimopoulos, Koulaidis & Sklaveniti, 2003). Example: experimental procedure, nitrogen cycle in nature etc.
4. Metaphorical: these images it's not symbolize meanings and values and they mostly associated with the cultural symbols (Dimopoulos, Koulaidis & Sklaveniti, 2003).

Results

The twelve science textbooks were analyze based on total number of representation and average number of representations per page (Table 2). 7th grade textbooks which is published in 2002 had more visual representations than others. 8th grade textbooks which is published in 2017 had less number of representations.

Table 2. Number of representations in textbooks

No	Grade	Year	# of Pages sampled	Total # of representations	Average # of representations per page
1	6th	2002	171	414	2.42
2	6th	2011	258	735	2.84
3	6th	2014	176	309	1.75
4	6th	2017	226	620	2.74
5	7th	2002	159	507	3.18
6	7th	2012	239	658	2.75
7	7th	2014	243	547	2.25
8	7th	2017	254	760	2.99
9	8th	2002	156	448	2.87
10	8th	2011	259	527	2.03
11	8th	2015	258	439	1.70
12	8th	2017	182	283	1.55

Analysis of 6th grade's textbooks based on graphical type showed that iconic diagrams is good sources to teach science concepts and increase conceptual learning. 2011 textbooks is better because it has more iconic images. Analysis of 7th grade textbooks based on graphical type showed that schematic diagrams are generally used in upper levels. We can see that 2017 textbook has more schematic images. In 8th grade textbooks, 2002 textbook had more schematic representations and 2017 textbook had lowest representation of graphical type among other textbooks.

6th grades textbooks analysis based on gender representation showed that 2011 and 2017 textbooks had more female representation than male representation. In 7th grade textbooks 2017 had more female representation than others. Among 8th grade textbooks, 2011 one has equal representation of female and male genders. However 2015 had lowest representation in both gender.

Analysis of 6th grade's textbooks based on indexing showed that overall all textbooks' had visual representation with indexing. 7th grade's textbooks analysis based on indexing showed that 2017 textbook had more visual image without indexing than others. In 8th grade textbooks, 2015 textbook had more none-indexing visual images while 2017 textbook has less number of none-indexing visual images.

Analysis of 6th grade's textbooks based on captioning showed that 2017 textbooks have a better representation in terms of captioning. 7th grade's textbooks analysis based on captioning showed that 2014 and 2017 textbooks

had more visual image without captioning than others while 2012 textbook have a better representation of visual images in terms of captioning. 8th grade textbooks, 2011 and 2015 textbook had more captioned visual images while 2002 textbook have more none captioned visual images.
In terms of formality of captioning conventional images have a strong, hybrid images have moderate and realistic images weak representation of visual images. Analysis of 6th grade's textbooks based on formality of visual image showed that 2011 textbook has more realistic images than others while 2017 textbook has more conventional images. 7th grade's textbooks analysis based on formality of images showed that 2017 textbook had more conventional images while 2014 textbook has more hybrid images. Also 2012 textbook has more realistic images than others. In 8th grade textbooks, 2002 textbook had more conventional visual images while 2011 textbook has more realistic visual images.

Analysis of 6th grade's textbooks based on formulas/equations showed that 2011 textbook has more visual and verbal formulas than others. 2014 textbook doesn't include any visual formulas. 7th grade's textbooks analysis based on formulas showed that 2012 textbook had more visual formulas and equations while 2014 textbook doesn't include any formula or equation at all. In 8th grade textbooks, 2011 textbook had more visual formulas while 2017 textbook have none. Also 2015 textbook has more verbal formulas and equations than others.

In terms of function of visual images classificational and analytical images emphasize strong visual images and narrative and metaphorical images emphasize weak visual images. Analysis of 6th grade's textbooks based on function of visual images showed that 2002, 2011, 2014 and 2017 textbooks have more analytical representation of visual images than narrative ad metaphorical images. 7th grade's textbooks analysis based on function of visual images all textbooks had good number of analytical images. In 8th grade textbooks, 2002 textbook had more analytical images than others while 2017 textbook have more narrative images.

Conclusion

Results of study showed that there is an increase status of representations in science textbooks. A general decline in the use of abstract representations and a major increase in more concrete and familiar representations (more iconic). An overall decline in formulas over time. Slough vd (2010) and Dimopoulos vd. (2003) research results support our findings. Realistic images use more frequently in textbooks. Female and male representations becoming better compared to old textbooks. Captioning in text is getting common to use. Analytical images is preferred to use from the textbooks authors. So, teachers should a criteria to select best textbooks and effective for their students. Science course materials should be prepared with appropriate visual materials.

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