academicJournals

Vol. 11(19), pp. 1841-1851, 10 October, 2016
DOI: 10.5897/ERR2016.2984
Article Number: 72EBE1C61005
ISSN 1990-3839

http://www.academicjournals.org/ERR

Educational Research and Reviews

Full Length Research Paper

Analysis of analogy use in secondary education science textbooks in Turkey

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Received 24 August, 2016; Accepted 26 September, 2016

Analogical reasoning is both an innate ability and a basic learning mechanism that can be improved. In classrooms, it is an important tool used by teachers, especially when explaining difficult or abstract issues. In addition to its use in all aspects of our lives, analogical reasoning is commonly used in textbooks. This research examines the extent to which analogies are used in high school science textbooks, the subjects of the examination being high school physics, chemistry, and biology course textbooks used by students between 14 and 17 years of age. A total of 15 textbooks (four biology books, five physics books, and six chemistry books) were reviewed. Ninety-two analogies were identified in these books. These analogies were classified based on a scheme developed by Curtis and Reigeluth. Findings are discussed in the context of previous related studies.

Key words: Analogy use, science education, secondary education, science textbooks, meaningful learning, cognitive science.

INTRODUCTION

Meaningful learning is directly related to students' ability to establish and integrate new and relevant existing knowledge (Ausubel 1980; Novak 1998). In this sense, analogies have potential to aid in understanding of new knowledge by highlighting similarities between existing known concepts (the *analog*) and new information (the *target*). For this reason, analogies can be efficient tools for meaningful learning. On the nature of analogies, Gentner (1989) comments, "the analogy conveys that a relational system in the target domain matches one in the base domain". *Base domain* refers to existing knowledge. As an example, the analogy of a continuous train operating on a closed-loop track can facilitate students' understanding of the movement of electric current in a torch bulb serial circuit (Figure 1, Dupin and Johsua, 1989). Passengers travelling from one point to another (analog) are likened to electrons (target). This analogy aims to help students comprehend that electric current is not consumed.

According to Venville and Treagust (1996), an analogy is a process of identifying similarities and differences between two objects or processes. Its purpose is to explain and name unknown cases via already known ones. This is called "analogical mapping" by Gentner (1998), and can be schematized as shown in Figure 2. Gentner (1998) describes analogy as follows:

Analogy is ubiquitous in cognitive science. First, in the

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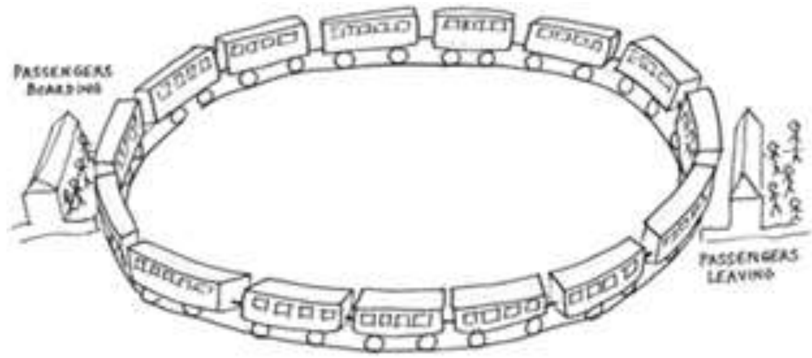

Figure 1. The continuous train analogy shows that current is not consumed in a series circuit (Harrison and Treagust, 2006).

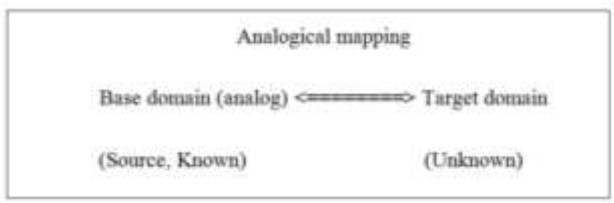

Figure 2. Analogical mapping of base and target domains (adapted from Wilbers and Dult, 2006).

study of learning, analogies are important in the transfer of knowledge and inferences across different concepts, situations, or domains. Second, analogies are often used in…reasoning. Third, analogies can serve as mental models for understanding a new domain (p. 107).

Analogical reasoning is a basic, common learning mechanism used as early as infancy (Goswami, 1992, 2008). Scientists have also benefitted from the use of analogies, as they are superior reasoning methods. Many scientific discoveries have been achieved with the help of analogical reasoning (Harrison and Treagust, 2006).

Analogies used in an active manner can be integral to learning because they have the potential to activate already known concepts (Duit, 1991; Glynn, 1991; Spiro,1988). Teachers find some specific analogies both efficient and useful. Examples of analogies used by teachers include the car analogy, which explains the importance of a balanced and healthy diet, and the genetic cookbook analogy, which explains DNA (Wormeli 2009). Students of many ages benefit from analogies, which assist them in understanding, visualizing, and remembering new concepts (Orgill and Bodner, 2007). Analogies are used to promote understanding in disciplines such as science (Harrison and Treagust, 2000a), mathematics (Richland et al., 2004), music (Stollak and Alexander ,1998), language education (Hulshof and Verloop, 2002), and art education (Casakin and Goldschmidt, 1999).

The positive effects of analogies on comprehension and retention have been identified with regard to topics including molecules and atoms (Harrison and Treagust, 2000a), electrical circuits (Chiu and Lin, 2005), genetics (Baker and Lawson, 2001), geology (Blake, 2004), chemical dissociation (Çalık et al., 2009), protein synthesis (Pittman, 1999), chaotic systems in physics (Duit et al., 2001), structure and properties of matter (Kobal et al., 2014), enzymes (Atav et al., 2004), and electrical current (Aykutlu and Şen, 2011). While highlighting the indispensable role of analogies in explaining theoretical or abstract concepts, Lawson (1993) argues for the necessity of analogical statements in learning subjects such as atomic structure, which students find difficult to grasp directly. Analogies can thus play a central role in restructuring students' conceptual frameworks (Duit 1991; Vosniadou 1994). According to Sutton (1992), the use of technical terms could lead to confusion and difficulty in students' learning of scientific concepts. To avoid this, analogical expressions or explanations, which make use of students' existing knowledge, should be used to simplify the cognitive processes involved in learning new material.

Venville and Treagust (1996) evaluated and classified the roles of analogies in the learning process into four main categories. The first category is the *sense maker* or *advance organizer*; it refers to analogies that provide an overview of a subject. The second category is the *memory aid*, which refers to analogies that contribute to retention of learning. The third category, *transformer*, refers to analogies with the ability to transfer knowledge from knowns (analogs) to unknowns (targets). The final category is that of the *motivator*, in which analogies raise students' interest in a subject or course.

However, although analogies can be important tools for understanding, they may also lead to misunderstandings and, therefore, they should be constructed properly in order to avoid this. To construct the best analogy, comparable and incomparable features of the analogs and targets should be interpreted clearly (Spiro,1988). Clarifying analogies in this way enriches them and makes them more effective (Duit et al., 2001; Glynn et al.,1989; Harrison and Treagust, 2006; Iding, 1997). For example, an analogy drawn between the eye and a camera can be powerful. Images recorded on the film in the camera can be thought of as similar to images formed on the retina of the eye and transmitted to the brain. A camera lens cap's protective function can be likened to the eyelid's protection of the cornea. However, the analogy breaks down at the following points: while cameras are sensitive to very bright light, the eye can adapt itself to both bright and dim light; and while cameras produce permanent single images, the eyes produce multiple, non-permanent images (Harrison and Treagust, 2006).

It is difficult to predict precisely when analogies will add to confusion and when they will contribute to understanding (Curtis and Reigeluth 1984). In classrooms, controlling this is the teacher's responsibility (Dagher, 1995; Nashon, 1994; Newton and Newton, 1995). In fact, different types of analogical models have been developed to aid teachers in using analogies for teaching. Glynn (1991) developed and suggested the six-step Teaching-with-Analogies (TWA) model, and Treagust et al. (1998) introduced the Focus, Action, Reflection (FAR) model.

Teachers are more successful in adapting existing analogies to specific cases than they are in generating analogies spontaneously. They also have difficulty generating enriched analogies. Accordingly, teachers require an extensive repertoire of analogies (Harrison 2001; Treagust et al. 1992). Textbooks can be considered key components of this repertoire. They are the most basic and accessible sources of knowledge for students, and they play a critical role in every stage of the learning processes of science classes. Moreover, teachers use textbooks significantly when planning the curriculum and determining their pedagogical strategies (Sánchez and Valcarcel 1999; Souza and Porto 2012).

However, teachers often find textbooks too general and outdated. They may, in these cases, use textbooks merely as a source for analogies (Mastrilli,1997), and thus the characteristics of analogies in textbooks can impact teaching strategies themselves. Additionally, according to Else et al. (2008), although students play an active part in employing and interpreting existing analogies in all their disciplines' curricula, they are incapable of generating analogies themselves. Given this, textbooks are primary sources for existing analogies used in teaching. According to Orgill and Bodner (2006), textbooks have the potential advantage of providing students with clearer and more extended analogies.

Classification of analogies

Analogies in textbooks and their related issues have been the subject of many studies (Curtis and Reigeluth, 1984; Çalık and Kaya, 2012; de Posada,1999; Demirci Güler et al., 2008; Giora, 1993; Glynn and Takahashi, 1998; Harrison, 2001; Iding, 1997; Orgill and Bodner, 2006; Thiele and Treagust, 1994; Thiele and Treagust, 1995). However, only a few of these studies have specifically classified analogies. Curtis and Reigeluth (1984) examined 26 science textbooks and classified analogies into six categories. Newton (2003) took the first five of these categories into consideration; Thiele and Treagust (1994) added three additional categories; and Orgill and Bodner (2006) expanded the original six categories to ten. Several studies have also examined analogies in Turkish textbooks in particular, at both elementary and secondary school levels (Çalık and Kaya, 2012; Demirci Güler et al., 2008; Dikmenli, 2010; Toprak and Pekmez, 2011; Yener, 2012). In these studies, the secondary level books were taken from specific branches of science (for example, biology, physics, or chemistry).

METHODOLOGY

Research questions

In this study, a relatively large number of high school science textbooks were analysed. Our research questions were:

RQ_1: How often are analogies used in secondary science education textbooks in Turkey?
RQ_2: Which types of analogies are used?
RQ_3: In which areas are analogies used frequently?

Since textbooks are teaching materials prepared in parallel with the curriculum, they can be regarded as parts of the curriculum. Data analysed in this study was collected from three research groups using similar analogical classification systems. This international comparison adds value to the study.

Document analysis strategies were conducted based on a qualitative research paradigm. Fifteen accessible textbooks for secondary science education courses (physics, chemistry, biology) were reviewed, all of which were selected by the Ministry of National Education (MONE) for use in the 2013-2014 school year in

Table 1. Levels of consistency between classifications of analogies conducted by the assessors and the researcher.

Variable	Assessor 1	Assessor 2	Assessor 3
Number of analogies agreed upon by both researcher and assessor	85	88	87
Reliability	92.39	95.65	94.57

Turkey. Analogical statements in the books were identified; these statements were then classified based on the scheme developed by Curtis and Reigeluth (1984).

Three experts in the field of analogical research (two with 12 years of experience, one with 18 years of experience) performed classification of the analogies identified by this research. Before conducting classification, the experts were introduced to Curtis and Reigeluth (1984) system. The experts made their classifications independently; level of consistency among the experts was then determined by comparing their classifications with those of the researcher. A reliability analysis was conducted using the following formula:

Reliability = agreement/agreement + disagreement x 100 (Miles and Huberman,1994)

The consistency rate was found to be at least 92.39% (Table 1). Miles and Huberman (1994) consider a study reliable if the consistency rate among two or more different field assessors (experts) is greater than or equal to 90%.

Examined textbooks

Turkey has a centralized education system: teachers must follow a national curriculum in formal education. They are therefore unable to determine their curriculum themselves. Science education at the primary level is presented in courses under the combined category of *science and technology*, and at the secondary level (9th grade to 12th grade) through courses under the separate categories of *physics*, *chemistry*, and *biology*.

Schools in Turkey select the textbooks to be used during the school year from among those textbooks approved by the MONE. The textbooks examined in the present study were those chosen by the MONE for use in the 2013-2014 school year. According to 2014 data, approximately 5.5 million students in Turkey continue their formal studies at the secondary level. Twenty-four percent of these students attend open institutions, and 75.9% attend public and private institutions (MONE, 2014). The textbooks examined were used by approximately 4 million students from private and public educational institutions in Turkey. Some textbooks were also produced by independent publishers. Details of the textbooks examined can be found in Table 2. The first five of the six categories developed by Curtis and Reigeluth (1984) were used in this research:

1. Analogical relationship: Structural (S), Functional (F), or Both (S&F). Three possible relational categories of analogical relationship can occur.

A. S: Parallels are drawn between appearance, physical organization, and/or structures.
B. F: Parallels are drawn with the way something behaves, functions, and/or operates.
C. S&F: Both structural and functional parallels are drawn.

2. Presentational format: Verbal (V), Pictorial (P), or Pictorial-Verbal (P-V).

A. V: Analogies can be represented in the text in verbal form, whereby the relationship is explained in words.
B. P: Analogies can be represented in the text in pictorial form, whereby the relationship is explained in pictures only.
C. P-V: Analogies can be represented by pictures accompanied by words.

3. Content condition: Concrete to Concrete (C-C), Abstract to Abstract (A-A), or Concrete to Abstract (C-A). The actual content that is chosen to create the analog and target may be categorized in a variety of ways. Curtis and Reigeluth (1984) mention three possible combinations.

A. C-C: Both the analog and the target are of a concrete nature.
B. A-A: Both the analog and the target are of an abstract nature.
C. C-A: The analog is of a concrete nature but the target is of an abstract nature.

Theoretically, there is also a fourth category, Abstract to Concrete (A-C). However, analogies aim to support understanding of difficult abstract concepts by linking them to concrete ones. Perhaps for this reason, A-C analogies were not encountered in the present study, nor were they included in that of Curtis and Reigeluth (1984).

4. Position in text: Advance Organizer (AO), Embedded Activator (EA), or Post Synthesizer (PS);

A. AO: Analogies are used at the beginning of a unit.
B. EA: Analogies are used to explain a subject requiring additional interpretation within a unit.
C. PS: Analogies are presented at the end of the unit in a summarizing capacity.

5. Level of enrichment: Simple (S), Enriched (En), or Extended (Ex); In this classification scheme, the boundaries of the analogy and its similarities with the target were considered.

A. S: Only a similarity statement is made between the analog and the target, with no further explanation of this similarity provided. For example, “Expansion of the universe after the Big Bang is like a balloon being blown up,” or “The DNA molecule is shaped like a twisted ladder.”
B. En: Further explanation of the similarity between an analog and a target are given. For example, “Activation energy is like a hill because you have to add energy to the reacting substances to start the reaction” (Harrison and Treagust, 2006).
C. Ex: Mixtures of S and En analogies; limitations are put on the similarities between an analog and a target, or both common and uncommon features of the analog and target are explained. The aforementioned analogy between an eye and a camera is an example of an analogy in the Ex category.

RESULTS

Descriptions of examined science textbooks

This research analysed a total of fifteen textbooks: four

Table 2. Science textbooks reviewed in the study.

Author (s)	Date of publication	Edition	Title	Publisher
S. Ercan Akkaya, O. Albayrak, E. Öztürk, Ş. Cavak	2012	Fifth	Biology 9	MEB Publishing
S. Ercan Akkaya, D. Sağdıç, O. Albayrak, E. Öztürk, Ş. Cavak, F. İlhan	2012	Fourth	Biology 10	MEB Publishing
D. Sağdıç, O. Albayrak, E. Öztürk, Ş. Cavak	2012	Third	Biology 11	MEB Publishing
S. İlhan (Ed.)	2012	Second	Biology 12	MEB Publishing
S. A. Kıray, B. Bektaşlı, G. Erbatur	2012	First	Physics 9	Pasifik Publishing
C. Kalyoncu, A. Tütüncü, A. Değirmenci, Y. Çakmak, E. Pektaş	2012	Fifth	Physics 9	MEB Publishing
C. Kalyoncu, E. Pektaş, A. Değirmenci, M. A. Kurnaz, A. Tütüncü, Y. Çakmak, G. Bayraktar	2012	Fourth	Physics 10	MEB Publishing
M. A. Kurnaz, A. Değirmenci, C. Kalyoncu, E. Pektaş, G. Bayraktar, U. Aydın, Y. Moradaoğlu	2012	Third	Physics 11	MEB Publishing
S. Çepni (Ed.)	2012	Second	Physics 12	MEB Publishing
H. Demirelli, N. Kavak	2012	Fifth	Chemistry 9	Mega Publishing
M. F. Dursun, İ. Gülbay, S. Çetin, Ü. Tek	2012	Fifth	Chemistry 9	MEB Publishing
M. F. Dursun, İ. Gülbay, S. Çetin, Ü. Tek, F. F. Özkoç, M. Güntut	2012	Fourth	Chemistry 10	MEB Publishing
N. Kavak	2012	Second	Chemistry 11	Mega Publishing
M. F. Dursun, İ. Gülbay, F. F. Özkoç, Ü. Tek, M. Güntut	2012	Third	Chemistry 11	MEB Publishing
O. Z. Yeşilel	2012	Second	Chemistry 12	MEB Publishing

biology textbooks, six chemistry textbooks, and five physics textbooks. The analogies identified and classified in the textbooks, those chosen from among the latest selections of the MONE in Turkey, are displayed in Table 3, stratified by text grade level. Analogies were encountered in all textbooks. A total of 92 analogies were detected across all books.

Physics textbooks had the most analogies (56 total), followed by chemistry texts (23 total). Only 13 analogies were detected among all the biology textbooks. The average number of analogies per textbook was 6.13 (SD = 5.14).

Categorization of analogies

Analogies in the textbooks were categorized and are illustrated in Table 4.

Analogical relationship

Most analogies in the secondary education science textbooks (66 analogies, 71.7%) were F analogies, followed by S analogies (15 analogies, 16.3%). The number of S&F analogies was low (11 analogies, 12%).

Table 3. Distribution of analogies in examined textbooks stratified by subject, specific topics, and grade level.

Grade	Subject	Number of analogies	Relationship			Presentation		Condition			Position in Text			Level of Enrichment		
			S	F	S&F	V	P-V	C-C	A-A	C-A	AO	EA	PS	S	En	Ex
Biology																
9	World of living things	4	1	2	1	3	1	2	0	2	0	4	0	2	1	1
10	Reproduction in living things	1	1	0	0	0	1	1	0	0	0	1	0	0	1	0
	Energy cycle in living things	2	2	0	0	2	0	0	0	2	0	2	0	2	0	0
11	Heredity	1	0	1	0	1	0	0	1	0	0	1	0	1	0	0
12	Animal and human biology	5	0	4	1	5	0	1	0	4	0	5	0	3	2	0
	Total:	13	4	7	2	11	2	4	1	8	0	13	0	8	4	1
Chemistry																
9, 10, 12	Chemical bonds	5	1	3	1	3	2	1	0	4	0	4	1	4	1	0
9	Chemistry in biological systems	1	0	1	0	1	0	0	0	1	0	1	0	1	0	0
10, 11	Electrochemistry	5	0	4	1	5	0	0	1	4	0	5	0	5	0	0
11	Energy in chemical reactions	2	0	2	0	2	0	0	0	2	0	2	0	2	0	0
9	Environmental chemistry	1	0	1	0	1	0	0	0	1	0	1	0	1	0	0
9	Mixtures	3	0	3	0	3	0	1	0	2	0	3	0	3	0	0
11	Nuclear chemistry	2	0	1	1	2	0	0	2	0	0	2	0	2	0	0
10	Structure of the atom	4	2	2	0	4	0	0	0	4	0	4	0	2	2	0
	Total:	23	3	17	3	21	2	2	3	18	0	22	1	20	3	0
Physics																
9, 10, 12	Composition of matter	14	2	10	2	10	4	3	1	10	0	14	0	10	3	1
11	Earth and space	3	0	3	0	2	1	0	0	3	0	3	0	2	1	0
10,12	Electricity	6	0	4	2	5	1	2	2	2	0	3	3	5	1	0
9, 12	Energy	2	0	1	1	0	2	1	0	1	0	2	0	2	0	0
9	Forces/Motion	2	0	2	0	0	2	0	0	2	0	2	0	2	0	0
9, 11	Magnetism	17	5	12	0	7	10	5	2	10	0	15	2	10	5	2
9, 10, 11, 12	Waves	12	1	10	1	6	6	3	0	9	1	11	0	9	3	0
	Total:	56	8	42	6	30	26	14	5	37	1	50	5	40	13	3

Presentational format

Most of the analogies (62 analogies, 67.4%) were the V type. P analogies were not encountered. The remaining analogies (30 analogies, 32.6%) were P–V.

Content condition

Most analogies (63 analogies, 68.5%) found were

Table 4. Number of analogies in each category of the classification system.

Category	n	Percentage (%)
Analogical relationship	92	-
Structural (S)	15	16.3
Functional (F)	66	71.7
Both (S&F)	11	12.0
Presentational format	92	-
Verbal (V)	62	67.4
Pictorial (P)	0	0.0
Pictorial-Verbal (P-V)	30	32.6
Condition of subject matter	92	-
Concrete to Concrete (C-C)	20	21.7
Abstract to Abstract (A-A)	9	9.8
Concrete to Abstract (C-A)	63	68.5
Position in text	92	-
Advance Organizer (AO)	1	1.1
Embedded Activator (EA)	85	92.4
Post Synthesizer (PS)	6	6.5
Level of enrichment	92	-
Simple (S)	68	73.9
Enriched (En)	20	21.7
Extended (Ex)	4	4.3

in C-A format, followed by C-C analogies (20 analogies, 21.7%) and finally A-A analogies (9 analogies, 9.8 %).

Position in text

Most of the analogies examined in secondary education textbooks were EA analogies (85 analogies, 92.4%), followed by PS (6 analogies, 6.5%) and AO analogies (1 analogy, 1.1%), respectively.

Level of enrichment

Most of the analogies in the secondary level textbooks examined were in the S enrichment category. Twenty analogies (21.7%) were classified as En, and four (4.3%) were classified as Ex.

DISCUSSION

Analogies can affect the attractiveness and fluency of textbooks (Orgill and Bodner, 2006). Developing analogies and keeping them up to date can increase the effectiveness of education, particularly in countries with centralized systems such as Turkey.

According to Orgill and Bodner (2006), textbooks have the potential to aid learning outside the classroom as well as inside. However, while teachers can correct erroneous inferences and interpretations of analogies in the classroom, analogies in textbooks may lead to mis-understanding or misinterpretation outside the classroom where the teacher is not present. These types of misunderstandings or misinterpretations can be avoided by enriching analogies—that is, by providing details on the extent and limitations of specific analogies.

In Curtis and Reigeluth (1984) study of textbooks in the USA, most analogies were identified as belonging to the En class (81.0%); in the present study of Turkish textbooks, most analogies were identified as belonging to the S class (73.9%). Very few Ex analogies (4.4%; see Tables 5 and 6) were identified. The textbooks examined in this study were used by nearly 4 million students of public and private educational institutions. Therefore, it may be important to develop and continually update the analogies used in textbooks, increasing their active use and improving the understanding of students in Turkey and similar countries. Other studies conducted in Turkey have found that both prospective teachers and existing academic staff lack knowledge on the nature and use of analogies (Beyazıt, 2011; Güneş et al., 2004). No studies on the status of teachers in this situation have yet been encountered; this topic should be examined in future research.

Recent studies of analogy have focused on students' generation of their own analogies (Pittman, 1999; Kobal et al., 2014; Kılıç, 2009). In experiments in which students generate their own analogies as substitutes for existing analogies, no meaningful differences in learning have been found (Kılıç, 2009; Kobal et al., 2014). Many studies do, however, report meaningful changes in teaching practices and progress in overcoming mis-conceptions through use of existing analogies (Atav et al., 2004; Aykutlu and Şen, 2011; Kayhan, 2009; Kılıç, 2009; Kobal et al., 2014; Şendur et al., 2008). These results indicate that existing analogies have the potential to contribute greatly to teaching. Course textbooks are one of the most important resources for existing analogies.

Students are successful in using and interpreting existing analogies, yet have difficulties generating analogies themselves (Orgill and Bodner ,2006; Else et al., 2008). Teachers use existing analogies in classrooms as well, and have difficulties generating new well-developed analogies (Oliva et al., 2007). Accordingly, teachers must have comprehensive repertoires of analogy, including tools such as course textbooks. Textbooks are also beneficial in that they present students with straightforward analogies outside of the

Table 5. Comparison of data from the present research with data from previous studies conducted on classification of analogies in textbooks.

Article	Akçay 2014[a]	Curtis and Reigeluth 1984[a]	Newton 2003[b]
Category		Percentage (%)	
Analogical relationship			
Structural (S)	16.3	25.0	65.2
Functional (F)	71.7	70.0	20.7
Both (S&F)	12.0	5.0	14.1
Presentational format			
Verbal (V)	67.4	84.0	78.3
Pictorial (P)	0.0	0.0	0.0
Pictorial-Verbal (P-V)	32.6	16.0	21.7
Content condition			
Concrete to Concrete (C-C)	21.7	12.0	59.8
Abstract to Abstract (A-C)	9.8	6.0	0.0
Concrete to Abstract (C-A)	68.5	82.0	40.2
Position in text			
Advance Organizer (AO)	1.1	23.0	0.0
Embedded Activator (EA)	92.4	76.0	100.0
Post Synthesizer (PS)	6.5	1.0	0.0
Level of enrichment			
Simple (S)	73.9	6.0	60.9
Enriched (En)	21.7	81.0	39.1
Extended (Ex)	4.4	13.0	0.0
Average number of analogies per book	6.1	8.3	2.6

[a]Analogies in secondary education; [b]Analogies in primary education.

classroom as well (Orgill and Bodner, 2006).

According to Harrison and Treagust (2000b), modelling, which is the essence of scientific study and thinking, possesses an essentially analogical structure. These authors argue that model-based thinking and model-based science are inevitable components of learning.

Past research has suggested that analogical reasoning processes are not acquired abilities. On the contrary, it appears that analogical thinking and related knowledge transfer processes are innate abilities. Although adults' and children's analogical comparison abilities are different, it is apparent that analogical reasoning processes are used at every age. Analogical reasoning abilities develop by themselves; even without guidance, children exhibit behaviours that suggest the use of analogical knowledge transfer processes. Moreover, the occurrence of spontaneous analogical transfer in children increases when they face problems repeatedly (Leech et al., 2008). We can thus conclude that analogical reasoning abilities begin to emerge during childhood and develop over an individual's lifespan. These abilities require support in order to develop properly. Textbooks may contribute this support in formal teaching situations. In addition, science fiction books may also contribute to the development of analogical thinking.

Teachers require knowledge of analogies that are pre-existing and have well-determined limits (Harrison and de Jong, 2005; Mastrilli, 1997; Treagust et al., 1992). The most accessible resource with which to meet this need is that of textbooks. Nowadays, textbooks are often widely available as e-books or digital internet files, and they maintain their standing as reliable, widely accessible sources of information in classrooms.

Conclusion

In terms of analogical relationships, the data in this study align with the results of Curtis and Reigeluth (1984) study on high school textbooks. F analogies were found to be the dominant type across textbooks from all three scientific disciplines. Conversely, Newton (2003) study of primary education textbooks found that 65.2% were S analogies. As Newton (2003) stated, this shows that as students get older, the analogies they encounter tend to grow more functional in structure. According to Curtis and Reigeluth (1984), a purely structural analogy focuses on a unique similarity between an analog and a target. However, the number of differences between an analog and a target is likely also high. Therefore, purely structural analogies may be weak. Curtis and Reigeluth (1984) suggested that functional analogies tend to be used to teach complex and abstract subjects. The functional analogy established by Newton (2000) between the human brain and a computer, for example, could assist students already familiar with computers to understand functional brain processes. Although the brain does not look like a computer and may not be organized like one, brains and computers nevertheless have some functions in common:

Target 1: Encodes information from the senses for processing
Analogy 1: Encodes incoming data for processing
Target 2: Holds and processes information in working memory
Analogy 2: Holds and processes data in random access memory (RAM)
Target 3: Stores information for later recall in long-term memory
Analogy 3: Stores information for later recall on a hard disk drive (HDD)
Target 4: Communicates outcomes of processing (e.g., by speech or writing)
Analogy 4: Communicates outcomes of processing (e.g., on screen or by printer)
(Newton, 2000)

The number of S&F analogies found in this study is more than double the number found by Curtis and Reigeluth (1984; also see Table 5). According to Curtis and Reigeluth (1984), S&F analogies are more comprehensive and therefore more powerful in terms of expression. It can thus be said that analogies in Turkish high school science textbooks are powerful in terms of their analogic relationships. The results of the three previous studies, as depicted in Table 5, show that the number of analogies per textbook at the secondary education level tends to be larger than that at the primary level. This result may be explained by the fact that analogies are usually used to teach abstract and complex subjects, and as children move from primary to secondary education, the topics they learn become more complex and abstract.

In terms of presentational format, V analogy ratios are found to be in accordance with the data from Curtis and Reigeluth's (1984) study. The ratio of P-V analogies is found to be twice that found by Curtis and Reigeluth (1984). P analogies were not found in any of the three studies described in Table 5. According to Curtis and Reigeluth (1984), the V presentational format may be sufficient for teaching analogical relationships. However, the P-V format is preferable for students at lower levels. This suggests that high school science textbooks in Turkey may be targeted toward students at lower levels. The data roughly confirm the findings of Curtis and Reigeluth (1984) with respect to content condition. However, in high school science textbooks in Turkey, the number of C-C analogies is remarkably high (Table 5). The excess of C-C analogies found in this research may have been distributed among the C-A and A-A classes in previous studies.

The number of AO analogies found was significantly lower than that found by Curtis and Reigeluth (1984), whereas the ratio of EA analogies was similar. Newton (2003), who examined primary education textbooks, found only EA analogies. The number of PS analogies found was significantly higher than that of Curtis and Reigeluth (1984). AO and EA analogies seem to be the best located analogies. In this respect, the analogies in Turkish high school science textbooks seem to be lower effective (Curtis and Reigeluth, 1984).

In terms of enrichment, most of the analogies found in Turkish high school textbooks are in the S class (73.9%). Very few analogies identified were in the Ex class (4.4%). In Curtis and Reigeluth's (1984) study, most analogies identified were in the En category (81.0%), followed by the Ex category (13.0%). In Newton (2003) study of primary school textbooks, no analogies were identified as belonging to the Ex class (Table 5).

According to Else et al. (2008), simple analogies are useful educational tools for creating general familiarity, because they provide entry-level knowledge about a completely unfamiliar topic. Bean et al. (1985) and Duit (1991) state that because of their structure, simple analogies are more helpful to students at lower levels than to those with deeper knowledge of a topic. The large number of simple analogies in Turkish high school science textbooks suggests that these books have been prepared with lower-level students in mind.

Many scholars have argued that a target concept can be taught more comprehensively by utilizing En analogies rather than S analogies, which concern only the most basic relationships (Duit et al., 2001; Glynn et al., 1989; Harrison and Treagust, 2006; Iding, 1997; Orgill and Bodner, 2006; Thiele and Treagust, 1994). In this sense, it is important to include high numbers of En and Ex analogies in textbooks. En and Ex analogies are those in which the limits of an analogy are determined accurately, and multiple mappings between the analog and the target can be established. Establishing these types of analogies may require more effort and additional research. Perhaps for these reasons, secondary education science text-books are less likely to contain En and Ex analogies.

Conflict of interests

The author has not declared any conflict of interests.

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