Domain-specific mappings as conceptual categorisers for scientific and technical vocabularies

Pilar Durán-Escribano and Irina Argüelles-Álvarez
Universidad Politécnica de Madrid (Spain)
pilar.duran@upm.es & irina.arguelles@upm.es

Abstract

The analysis of metaphorical lexical units in science and technology provides evidence for their existence either as separate cases or as part of a corresponding conceptual metaphor. In conceptual metaphors, metaphorical expressions constitute productive patterns that unveil the mental mappings that support technical and scientific thought, proving to be a powerful device for conceptualization and a prolific driving force for language growth (Lakoff & Johnson, 1980). Although conceptual metaphor cannot account for all types of linguistic metaphor (Evans, 2013), in this paper we have focused on the former because it implies a systematic set of correspondences between different domains of science and technology supporting the role of conceptual metaphor as a powerful theory constitutive element. The study is based on the qualitative analysis of the metaphorical lexical units included in eight widely accepted specific dictionaries, totalling over 790,000 entries. Attention is focused on domain-specific mappings, in which not only the target but also the source domain pertain to scientific fields, and where the corresponding linguistic expressions keep their univocal meaning in each field. Thus, providing examples from two apparently unrelated fields, earth sciences and telecommunications engineering, the role of domain-specific mappings as conceptual categorisers is studied, underlying the different degrees of categorization involved in the building of new theories (Boyd, 1993), in definitions, and in the expression of new concepts.

Keywords: metaphor in science, domain-specific mappings, theory-constitutive metaphor, metaphorical lexical concepts.

Resumen

Las correspondencias entre dominios específicos como categorizadores conceptuales del vocabulario científico y técnico

El análisis de las unidades léxicas metafóricas en la ciencia y la tecnología demuestra que aparecen tanto por separado como formando parte de una metáfora conceptual. En la metáfora conceptual, las expresiones metafóricas constituyen patrones productivos que revelan los mapas mentales que sirven de base al pensamiento técnico y científico y que son una valiosa herramienta para la conceptualización y un potente motor para el desarrollo del lenguaje (Lakoff & Johnson, 1980). A pesar de que las metáforas conceptuales no engloban todos los casos de metáforas lingüísticas (Evans, 2013), en este trabajo se profundiza en las primeras porque representan un conjunto sistemático de correspondencias entre diferentes dominios de la ciencia y la tecnología, apoyando el papel de la metáfora conceptual como un poderoso elemento constitutivo de las teorías científicas. El estudio se basa en el análisis cualitativo de las unidades léxicas metafóricas encontradas en ocho diccionarios específicos aceptados por los profesionales del campo, con un total de más de 790.000 entradas. Profundiza en las correspondencias entre dominios específicos en las que tanto el dominio fuente como el dominio meta pertenecen a áreas científicas, y donde las expresiones lingüísticas mantienen su significado unívoco en cada una de ellas. Basándonos en casos tomados de dos campos aparentemente inconexos, las ciencias de la tierra y la ingeniería de telecomunicaciones, se señalan los distintos grados en los que la categorización sustenta la construcción de nuevas teorías (Boyd, 1993), las definiciones, y la expresión de conceptos nuevos.

Palabras clave: metáfora en la ciencia, mapas conceptuales entre dominios específicos, metáforas en la construcción de teorías, conceptos léxicos metafóricos.

Introduction. Metaphor in science and technology

According to Lakoff & Johnson (1980: 3-4), metaphors are not just a way of expressing ideas by means of language, but a way of thinking about things. Early studies on figurative language in science show its frequent occurrence underlying scientific argumentation. Moreover, "metaphor plays an essential role in establishing links between scientific language and the world" (Kuhn, 1993: 539). Lakoff (in Brown, 2008: book-cover), commenting on "*Making Truth. Metaphor in Science*", affirms,

> Brown demonstrates that metaphorical thought is central in all branches of science, just as it is in everyday life and mathematics. Particles as waves, time as a spatial dimension, gravity as the curvature of space-time, ion channels, protein folding. All these crucial metaphors allow us to understand science in terms of our embodied experience.

Furthermore, interest in metaphor in science and technology has gradually increased from the last decade onward (Brown, 2003/2008; Knudsen, 2003; Colburn & Shute, 2008; Musolff, 2009; Hidalgo-Downing & Kraljevic-Mujic, 2009; Nerlich & Jaspal, 2012; Cuadrado & Durán, 2013a, 2013b; Roldán-Riejos & Úbeda-Mansilla, 2013; Zeidler, 2013; Roldán-Riejos & Molina-Plaza, 2016; Koteyko & Atanasova, 2016).

Previous research on the language of Information Technologies (IT) shows that the presence of metaphor in computer science has been broadly demonstrated (Fauconnier, 1997:18-22; Colburn & Shute, 2007, 2008; Porto-Requejo, 2007b; Lindh, 2016, among others). As Colburn and Shute (2008: 526) put it, "the language of computer science in general and software development in particular, is laced with metaphor". The terminology of computer science has also been a source of metaphors for other sciences, namely cognitive psychology (Boyd, 1993: 486). However, less attention has been paid to a closely related field, as is the area of telecommunications (Argüelles & Cuadrado, 2005). An analysis of the language of IT indicates the presence of metaphor in many other fields connected to IT, such as electronics and IT topology, which have not been adequately addressed so far. There remains a need for further studies to identify the complex interactions within metaphorical terms' networks in different scientific fields, as it is the case of earth sciences and telecommunications engineering, among others. Therefore, this work aims at contributing to unveil the deep structural relationships and analogies between such apparently unrelated fields. It will also analyse other correspondences between architecture and agronomy as the source shared in common with geology and IT as the target, highlighting those aspects of the source domains that have provided the metaphorical structuring of two apparently unrelated target domain sets of concepts.

Domain-specific mappings

By "domain-specific" mappings, we mean those cross-domain mappings where not only the target but also the source domain vocabulary pertain to specialized fields. Analysing the language of computer science, Fauconnier

(1997: 18) states, "[w]e can all see that vocabulary from the domain of health, biology, and medicine is being used to talk and reason about the domain of computers and programming. Viruses have been mapped onto undesirable, harmful programs … Vaccines are mapped onto programs". In the same way, in Earth Sciences we find several instances in which its specific vocabulary originates from mappings based on other specific domains. For instance, the term "barren" from biology is mapped onto geology and mining as in "barren rock", or "ore barrenness" to talk about rocks containing no minerals of value; the same with the term "consanguineous", as in "consanguineous rocks" to refer to rocks of related origin. The abundant occurrence of this type of mappings allows concluding that rocks are conceptualized as living organisms. Other cases of domain-specific mappings from technological fields (Gentner & Gentner, 1983) are the terms "current", as in "electric current", or "electromagnetic current"; and "flow" as in a number of collocations of which "electric flow", "control flow" and "data flow" are only some examples. These and other similar metaphorical lexical units reveal the framing of electronic mechanisms as natural phenomena.

When such metaphors are operative, we focus on a selection of features from the source that activate a new mental space shared in common with other scientific domains. This is the case of biology and geology, or hydrology and IT, where "A given metaphor highlights certain features of the source domain and hides others … Metaphors stimulate creation of similarities between the source and target domains, such that the target domain is seen in an entirely new light", explains Brown (2008: 29). As will be seen in the discussion of results section, the mappings that link these specific mental spaces in the given examples operate at high levels of scientific thought, and become a central element of meaning construction. However, previous literature on the subject reveals that cross-disciplinary mappings in science and technology have been under-researched so far, particularly those mappings that extend to frame a new knowledge area, as it is the case with new technologies borrowing concepts from older sciences (Durán & Argüelles, 2016: 109).

Although scientific terms in general are not context-dependent (e.g. "atom", "gene", "byte"), metaphorical terms need to be linked to specific areas of science and technology in order to be understood (e.g. "dome" in architecture mapped onto "dome" in geology; "avalanche" in earth sciences mapped onto "avalanche" in telecommunications). Thus, in our analysis, we will consider specific contexts because separating metaphor from its knowledge field may cause difficulties for comprehending the metaphor (English, 1998; Charteris-Black, 2004: 19; Porto-Requejo, 2007a; Kövecses, 2009). The fact that both source and target linguistic expressions keep their univocal meaning in their domain is important (e.g., "valley" "an elongated depression between uplands" in geography, and "the minimum value of a signal" in telecommunications) because science is characterised by the absence of ambiguity, and its language is correspondingly precise and unambiguous (Ortony 1993: 1).

Conceptual categorization

"Metaphors as linguistic expressions are possible precisely because there are metaphors in a person's conceptual system", affirm Lakoff and Johnson (1980: 6). Metaphor structures concepts in the target domain and, therefore, knowledge. Thus, it is not only a basic mechanism for understanding and categorising the world, but also a fundamental tool in human mental activities of reasoning and inferring, which conveys and generates new meaning (Lakoff & Johnson, 1980: 10-11).

According to Fauconnier (1997: 21), "language reflects to some degree the presence of analogical categorization and conceptualization by allowing the vocabulary of a source domain to apply to counterparts in the target". Thus, the new metaphorical term gives evidence of the role of the source domain in providing conceptual categorization for the target. Moreover, an important finding of cognitive semantics and mental-space research is that "the same mapping operations and principles are at work in elementary semantics, pragmatics, and so-called higher-level reasoning", as Fauconnier (1997: 5) points out. Mental spaces are defined by Fauconnier (1997: 34) as "the domains that discourse builds up to provide a cognitive substrate for reasoning and for interfacing with the world", in our case, with new scientific concepts and models. Thus, in this article, we will analyse those "domains" shared by scientists in their higher-level reasoning operations when they draw from their previous conceptual network the required concepts to describe new realities.

The models and theories that scientists use to explain their findings constitute metaphorical constructs (Thibodeau & Boroditsy, 2011). Although theory-constitutive metaphors are not usual, when successful, the scientific community readily incorporates them. According to Cornelissen and Kafouros (2008: 373), the impact of a metaphor on theory is determined by the ease with which it is understood and perceived to capture multiple features of the target, as well as by its potential to clarify concepts. Theory-constitutive metaphors are heavily based on the users' ability to apprehend the similarities and analogies between the primary and the metaphorical meaning, and they are used when there is a high degree of similarity between them (Boyd, 1993: 487-490). Thus, metaphors become part of scientific theory construction and of the explanation of theoretical concepts, including term's definitions, as we shall verify later.

Linguistic and conceptual metaphors

Not all metaphors are mappings of entire domains, with structural relationships between entities, actions and attributes. Corpus-based research has shown that linguistic metaphors may appear independently or in groups of metaphorical concepts, argues Deignan (2016: 107). In scientific and technical language, the majority of metaphors and metonymies appear to address specific communicative needs, most frequently based on analogy. Evans's (2009, 2013) Lexical Concepts and Cognitive Models Theory (LCCMT) provides a complementary approach for the analysis of metaphorical expressions. It is a linguistically mediated meaning construction theory, including the semantic and the conceptual representations of language. The presence in discourse of "resemblance metaphors", which coexist with conceptual metaphors, supports the author's belief that "the claim for conceptual metaphor as the underlying motivation for all linguistic metaphors may not, in fact, hold" (Evans, 2013: 81). Conceptual metaphors are mappings that "inhere in the conceptual rather than the linguistic system. They are relatively stable in long-term memory and are invariably activated during symbolic processing" (Evans, 2013: 84). On the other hand, resemblance metaphors, which may appear in isolation as discourse metaphors, may be perceptual (image) or functional. An image metaphor (X is a Y) involves understanding one entity in terms of aspects of the perceptual experience associated with another, whereas in functional resemblance, the mental comparison is motivated by the similarity in purpose of source and target words. Furthermore, conceptual metaphors are firmly established knowledge structures, while meaning is a flexible, open-ended, and dynamic process accounting for the occurrence of linguistic metaphorical expressions (Evans, 2013: 91).

In the coming sections we will analyse the role of conceptual metaphors as conceptual categorizers of scientific and technical vocabularies, trying to disclose their categorization potential. We will first discuss the methodology followed to identify metaphorical expressions in specific contexts. Then, we will describe those conceptual metaphors that frame a new area of knowledge in geosciences and in telecommunications, arguing that they represent very productive sources of new lexical units in most cases. Next, following Fauconnier's assert that "metaphorical vocabulary highlights the role of the source domain in providing conceptual categorization for the target" (1997: 21), we will deepen into the role of domain-specific mappings as conceptual categorizers, where both source and target words are part of different specific-domains. Finally, we will analyse the different degrees of categorization involved: from theory-building conceptual metaphors with a definitive role in scientific thought and language (Boyd, 1993; Kuhn, 1993; Brown, 2003/2008), to groups of metaphors that reinforce the existence of the human mind mapping mechanisms to express concepts linguistically (Grady, 1997; Evans, 2013; Deignan, 2016).

2. Methodology

Regarding the methodology followed to gather and analyse the data, this study is mostly based on the qualitative analysis of metaphorical lexical units included in the *Bilingual Dictionary of Scientific and Technical Metaphors and Metonymies* (Cuadrado et al., 2016) (BDSTMM)[1], though not exclusively (Table 1). We have incorporated new metaphorical entries as we have come across them in qualified technical dictionaries and specific vocabularies, as well as other derived terms used in the literature (see endnote 2). Their identification procedure in all cases is based on the principles of the Pragglejazz Group (2007), generally accepted in this type of endeavours (Siqueira et al., 2009: 162-163), which may be synthesized as follows:

- Identification of potentially metaphorical lexical units in qualified dictionaries (in our case), checking their definitions in field-specific vocabularies, and their use in on-line specialized journal articles, whenever necessary. Since we are dealing with cross-domain mappings where both source and target expressions belong to scientific or technical fields, both primary and metaphorical meanings were confronted in the corresponding specialised monolingual dictionaries. This search has revealed the central role of metaphor in defining metaphorical terms (e.g., identical rock crystals are "twins", or the "flow" of electric charge is an "electric current").

- Comparison of their specific context meaning in both source and target special contexts. For example, the meaning of "consanguineous" in geology, applied to rocks, compared to its primary meaning in biology:

  "*Consanguineous* Archaean intrusive and extrusive *rocks*, Noranda, Quebec: Chemical similarities and differences". "Plutonic, volcanic and minor intrusive rocks formed in the Noranda area during a few million years of Archaean time have similar compositions (in terms of Si, Ti, Al, Mg and total Fe), indicating a common *parentage*[2]" (Goldie, 1979: 275). [URL: https://doi.org/10.1016/0301-9268(79)90007-X]

- Contrast of the basic and the specific contextual meanings to find out whether the new meaning includes non-literal information other than the original meaning of the lexical unit. Whenever its contextual meaning was distinguished from its basic meaning, and could be understood by comparison with the latter, the word was considered metaphorical. Turning to the example given above, "consanguineous" in the source domain relates to people descended from the same ancestor, whereas in geology, "consanguineous" refers to associations of rocks of related origin.

The referential corpus

Specialized language dictionaries widely accepted by a discourse community may be considered a reliable source of reference for the search of metaphoric lexical concepts. According to Deignan, a dictionary written using corpus data gives "positive evidence" of the existence of linguistic metaphors and of metaphors apparently realizing a conceptual metaphor. However, "[i]f the dictionary does not attest other linguistic metaphors, this cannot be taken as evidence that they do not exist. They may not be frequent enough to warrant their own sense in a dictionary entry" (Deignan, 2015: 147) (see endnote 2). In Appendix 1, we present a table with the best-known specific dictionaries that constitute the corpus for this study, showing their features and the number of entries (Table 9). They give "positive evidence" of the presence of metaphor in the fields of earth sciences and telecommunications engineering. Other dictionaries consulted are included in the bibliography.

Analysis of prototypical cases of domain-specific mappings in Earth Sciences and Information Technologies

As we have said, metaphors are generally considered as conceptual categorisers. In the following sections, we will try to analyse their categorising function beginning with the field of geoscience to move on to information technologies.

Domain-specific mappings in Geoscience

Let us begin with the conceptual metaphor ROCKS AND MINERALS ARE HUMAN BEINGS (Table 1). It is analysed presenting the source domain, the mappings involved, and the metaphorical expressions as they are used in geoscience specific contexts. The source domain draws concepts from social sciences, biology, and genetics. Monolingual specific dictionaries were used (Appendix 1) to define metaphoric terms, unveiling the mappings* included in each case.

Source domain	Mapping* → Target domain	Metaphorical expression
Human family	a class of minerals and rocks is a family	family of rocks, related rocks
Biology	identical rock crystals are twins	twin crystals, twin rocks, to twin, twinning, twinning plane, contact twin,
Marital relationship	the union of two elements that produce new substances is	coupling
Biology / Reproduction	material from which the soil is formed is	parent material, parent substances,
Biology / Reproduction	rock or material not containing minerals of value is barren	barren rock, barren vein, barren block, ore barrenness, dead rock,
Biology / Reproduction	rocks and minerals from which other rocks and minerals are descended are parents	parent rock, mother rock, mother stone, parent body, parent mineral, parentage, parental rocks, parent element
Nurturance, care	a rock that contains other rocks or mineral deposits is a host or a bed	host rock, bedrock; bedded ore, bedded rock, bedded deposit, bedded ore
Genealogy	an organism from which later organisms descend is an	ancestor; ancestral organism,
Genealogy	an element descending from another is a descendant	daughter element, descendant, to descend, daughter composition

Genetics	the genetic relationship of igneous rocks is consanguinity	consanguineous rocks, consanguineous association
Social behaviour	a group of interdependent minerals in the same region that share some characteristics in common is a	community of minerals, accompanying mineral
Social behaviour	all the organisms that constitute a specific group or occur in a specified habitat is a	population, native mineral
Social behaviour	a gathering of minerals that form together in a rock at the same pressure and temperature at a given time is a	mineral assemblage, mineral association
Social behaviour	a part of a lithostratigraphical formation is a	member
Social behaviour	the forcing of molten rock into an earlier formation is an	intrusive rock
Social behaviour	rocks belonging to related families ranking between an order and a class are	allied rocks

Table 1. ROCKS AND MINERALS ARE HUMAN BEINGS.

Lakoff's (1993) model of "mother" encompasses five aspects: birth, marital, genetic (supplies genetic material), nurturance (takes care), and genealogical. As we can see, all these aspects can be applied to ROCKS AND MINERALS ARE HUMAN BEINGS except for birth (Cuadrado & Durán, 2013b: 59). However, further metaphorical correlations linking human behaviour to rocks take place, as are the cases of social behaviour and parenthood.

According to Wacker (1998: 361), any theory is based on four criteria: conceptual definitions, domain limitations, generalizability, and predictions. Theory building is important because it provides a framework for analysis, provides consistency for the development of the field, and is necessary for the applicability to practical real world situations. This is the case with ROCKS AND MINERALS ARE HUMAN BEINGS, which allows geoscientists to understand, give name and structure the realities involving the origin, composition, evolution, and relationships of rocks and minerals. Correspondingly, all the related metaphorical expressions reveal the existence of such powerful conceptual categorizer.

A second group of metaphorical expressions linked to the conceptual metaphor ROCK PROCESSES ARE PLANT PROCESSES is analysed in Table 2. The source domain categorizers originate in agroforestry and agriculture to express those processes undergone by rocks after weathering, and their resulting appearance. The mappings* here focus on rock transformation processes, unveiling a structural relationship between rocks and plants. As can be seen, in the two conceptual metaphors just discussed, different degrees of conceptualization and categorization outstand: the second case is not as complete as the first one.

Source domain	Mapping* → Target domain	Metaphorical expression
Agroforestry	the phase of weathering involving the breaking loose of thin slabs, spalls or flakes from rock surfaces is "exfoliation"	foliation, exfoliate, rock peeling
Agriculture	separate particles of detrital rock material (forming a loose mass of sand) are "grains"	sand grains, grained rock, granular texture
Agriculture	the part of a rock formation that appears at the ground surface is an "outcrop" or a "shoot"	rock outcrop; cropper, crop-end, outcropping, ore shoots; buried outcrop; to crop out;

Table 2. ROCK PROCESSES ARE PLANT PROCESSES.

A third case of domain-specific mapping categorization of rock structures comes from architecture and building (A&B), where we find expressions with functional (e.g. "floor", "chimney"), and visual (e.g. "dome", "chimney rock") metaphorical relations. This integrated schema of architectural elements mapped onto rock formations (Table 3) is more productive in terms of occurrences than the previous one; nevertheless, it corresponds to rock formations only, in the same way that the previous one refers to rock processes alone (Table 2). In both cases, the mappings* involved are essential to the technical definitions, as can be seen in the central column of Tables 2 and 3. The force of the mapped words is active giving rise to new metaphorical expressions, as shown in the right hand column. However, the mapping categorization mechanisms shown in ROCK FORMATIONS ARE ARCHITECTURAL ELEMENTS may be considered of a narrower scope than those discussed in the case of rocks and minerals conceptualized as human beings (Table 1).

Source domain	Mapping* → Target domain	Metaphorical expression
A&B	a smoothly rounded summit of rock that resembles the cupola on a building is a "dome"	dome crest, dome fold, salt dome, volcanic dome,
A&B	the rock immediately above a coal seam is the "roof"	roof rock, roofing,
A&B	the stratum that lies over the ore body is the "ceiling"	cavern ceiling, ceiling cavity, ceiling channel, ceiling tube, ceiling pocket,
A&B	the rock underlying a nearly horizontal deposit is the "floor"	floor break, floor cut, floor burst,
A&B	country rock bounding a vein laterally is a "wall"	wall cavitation, wall face
A&B	an elongated body of mineral is a "pipe"	window pipe
A&B	pipe-like more or less vertical opening in the earth is a "chimney"	chimney arch
A&B	a column of rock rising above its surrounding is	chimney rock
A&B	a body of ore with definite boundaries is a "chamber"	chamber deposit, chamber blast, chambered lode
A&B	a circular or ellipsoidal erosional break is a	window

Table 3. ROCK FORMATIONS ARE ARCHITECTURAL ELEMENTS.

Figure 1. "Dome crest". From photobucket.com/images/dome.

Domain-specific mappings in Information Technologies

The analysis of conceptual metaphors and metaphorical expressions dealt with in the previous section may be equally applied to metaphor use in the more recent technical field of Information Technologies (IT). We will start by analysing the mappings* from the field of architecture and building

(A&B) – just discussed in relation to rock formations – onto IT layouts (Table 4).

Source domain	Mapping* → Target domain	Metaphorical expression
A&B	organization of data in a computer is	structure
A&B	designing a system that meets certain requirements is	architecture
A&B	a vertical arrangement of data is a "column"	column balance, column guide, column indicator
A&B	a section of a screen is a "window"	floating window, cascade windows
A&B	virtual platforms to display posts are "walls"	social wall, social media wall
A&B	a logical electronic circuit is a "gate"	gate array, gate circuit, gate delay
A&B	a sudden drop in the digital signal is	brickwall effect
A&B, civil engineering	the path along which digital information travels is a "channel"	channel capacity, channel design
A&B, civil engineering	communication equipment between two networks is a "bridge"	bridgeware
A&B, civil engineering	the conversion of data or signal formats by embedding protocols is	tunneling
A&B	the current taken from a voltage source is a "drain"	current drain, drain wire
A&B	transmitting by a line connected to a based network is "building-out"	building-out circuit, building- out network, building-out section

Table 4. IT LAYOUTS ARE ARCHITECTURAL/ BUILDING CONSTRUCTIONS.

In this conceptual metaphor, most metaphorical expressions belong to the area of computing science, an extremely productive field as regards metaphor creation. Interestingly, it is also frequent to find similar conceptual mappings from the source domain of A&B onto the area of telecommunications. However, whereas most of the mappings from architecture and civil engineering are shared in both IT sub-disciplines (e.g. "channel", "bridge", "tunneling"), some others are exclusively found in the area of computing science (e.g. "architecture", "column"). Similarly, there are a few source domain terms from architecture, and more frequently from building, which are predominantly found in telecommunications (electronics), as are the structural metaphors "current drain" and "building-out circuit" (Table 4). Thus, IT LAYOUTS ARE ARCHITECTURAL/ BUILDING CONSTRUCTIONS is a conceptual metaphor that provides a stable framework to understand and explain abstract IT layouts.

Agroforestry is another specific source domain productive in the fields of computing science and telecommunications. The tree visual representation is a metaphor present in other scientific fields besides IT. However, in this case, the parts of the tree refer to parts of the IT topology, acquiring a definite role in concept designation (Table 5), because in telecommunication networks, its physical distribution, known as the "network topology", is a key factor.

Source domain	Mapping* → Target domain	Metaphorical expression
Agroforestry	the origin of a tree diagram is the "root"	root segment, root component
Agroforestry	the path over which information travels in a computer is the "trunk"	trunk [comp sci]
Agroforestry	a circuit connecting two telephone centrals is the "trunk"	[comp sci & telecom] trunk exchange, trunk group
Agroforestry	any one of a number of instruction sequences in a program is a "branch"	branch [comp sci]
Agroforestry	a portion of a network is a "branch"	[comp sci & telecom] branch current, branch gain

Table 5. IT TOPOLOGY IS A TREE.

Though probably not as evident as the conceptual metaphors on Tables 4 and 5 to the average technical language user, other more complex metaphors are frequent in telecommunications where they play a fundamental role in meaning construction, especially in those cases where the metaphor is constitutive of the theory with which it is related (Boyd, 1993: 486). In what follows, we will explore other more complex cognitive metaphors that have become powerful conceptual categorizers. We will focus on geoscience as the source domain in order to explain recurrent analogies in the area of telecommunications as our target, since it is one of the most productive fields feeding such analogical mappings. We will describe several mappings from hydrology (Table 6) and geology (Table 7), providing examples of related metaphorical expressions, and explaining their connections with other scientific and technological fields to create further new concepts from word combinations or collocations.

Source domain	Mapping1 → Target domain	Metaphorical expression
Hydrology	the flow of electric charge is	electric current
Hydrology	the flow of information is	data flow, traffic flow
Hydrology	excess of information is	overflow
Hydrology	logical groups of items used to organize, manage, and analyze is	overflow bucket, overflow storage
Hydrology	a series of components where the output of the first device serves as the input for the next stage is a 'cascade'	cascade amplifier, cascade connection, cascade server, cascade junction, cascade noise
Hydrology	an arrangement of windows such that one overlaps the following is	cascade windows
Hydrology	the effect of making text on the screen fall down to the bottom of the screen is	cascade virus
Hydrology	the videoconferencing method for allowing multiple participants to join in the conference is	cascading
Hydrology	processed data distributed to videoconference participants is a	stream, stream output
Hydrology	a structure used for the transport of low rate signals is a	tributary
Hydrology	oscillations of electric and magnetic fields are 'waves'	electromagnetic waves; wave propagation, wave frequency, wavelength

Table 6. ELECTRIC/INFORMATION MOVEMENT IS WATER FLOW.

One of the most productive mappings in ELECTRIC/INFORMATION MOVEMENT IS WATER FLOW (Table 6) is "cascade". A cascade is defined as "[a] small waterfall or series of falls descending over rocks" (*McGraw-Hill Dictionary*). In IT, a series of components or mechanisms where the output of the first serves as the input for the next is a "cascade". This metaphorical term appears in different contexts in technology, taking different meanings depending upon the specialization area. It is a clear case supporting our stance that metaphorical terms need to be linked to specific areas of science and technology in order to be understood as such. Thus, in electronics, a "cascade" is a series of components where the output of the first amplifying device serves as the input for the next stage multiplying the effect of each individual device. It becomes very productive in new lexical units such as "cascade amplifier", "cascade connection" (Figure 2), "cascade junction" or "cascade noise". Secondly, in videoconferencing, "cascading" is used to describe the method for allowing multiple participants to join in the conference. "Cascading" (*conexiones multipunto en cascada*) means to connect two separate Multipoint Control Units, where the second Multipoint Control Unit acts as a "host" distributing the processed data or "streams" to the videoconference participants (Webopedia). Thirdly, in computer science, this metaphor is used to conceptualize the behaviour of a computer virus, “cascade virus” (*virus en cascada*). The virus, which does not exist any longer, used to cause the characters to fall to the bottom of the screen. Finally, “cascade server” (*servidor en cascada*) is a content management system that permits the organization of multiple pages most commonly known in the general language as “cascade windows” (*ventanas en cascada*) in order for the user to arrange multiple windows open on a computer screen.

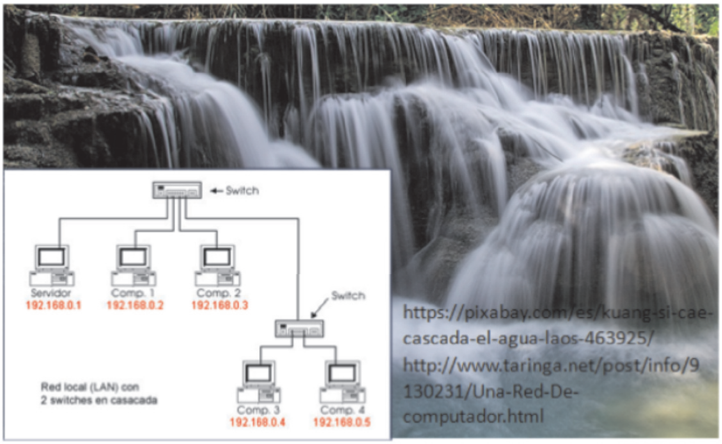

Figure 2. “Cascade connection”.

The mapping of a stream onto processed data is also used in telecommunications, alone as well as collocated with a number of terms: “stream job” or “stream output” to explain the behaviour of a “current” in electricity; or “data stream”, in computing science. Similarly, the use of “tributary” to describe a structure used in the transport of low rate signals. Water is also central in the analogy of sound or electromagnetic waves, which give birth to new metaphorical expressions such as “wave propagation”, “wave frequency” or “wavelength” based on their image and function. Also interesting as an image metaphor in electronics is the definition of “wave tail” or “wave trap” (also known as “trap”), which complement the previously mentioned metaphorical expressions containing “wave”. As we can see, in most of the cases of the lexicalised metaphors we have just explained, metaphorical mappings are still active and continue to generate new metaphorical terms and expressions (Fauconnier, 1997: 22), as we said in the introduction. These metaphors are entrenched in the new technical vocabularies providing firm support not only for the expression of new ideas by means of language, but for thinking about them, that is, for theory development.

Another prolific example of conceptual metaphor in telecommunication, based on geological features (field, valley, peak), and geological events (avalanche) is ELECTRONIC TRANSMISSION MOVEMENTS ARE GEOLOGICAL FEATURES AND EVENTS (Table 7). It is a further important case of theory constitutive metaphor.

Source domain	Mapping* → Target domain	Metaphorical expression
Geology	the set of devices necessary to create an electronic connection is a "path"	path attenuation, path coefficient
Geology	the space created around any electric force is a "field"	field effect, electric field
Geology	the maximum value of a signal is the "peak"	peak value, peak power, peak load
Geology	the minimum value of a signal is the "valley"	valley attenuation
Geology	the cumulative process in which electrons collide liberating additional electrons that collide is an "avalanche"	avalanche effect, avalanche breakdown, avalanche noise, avalanche oscillator, avalanche transistor
Geology	a given area or zone is	region
Geology	a total and sudden signal fall is a "cliff"	cliff effect, digital cliff
Geology	the relief of a gradient used for image processing and segmentation is	watershed

Table 7. ELECTRONIC TRANSMISSION MOVEMENTS ARE GEOLOGICAL FEATURES AND EVENTS.

In this conceptual metaphor, it is worth highlighting the natural phenomenon of an "avalanche", as it is rich in metaphorical expressions such as, "avalanche noise" (*ruido de avalancha*), a form of noise produced "in a region" close to the point of "avalanche breakdown" (*ruptura de avalancha*); as well as "avalanche effect", and "avalanche oscillator". A further case of conceptual transposition is "cliff" to conceptualize the "cliff effect" or "digital cliff" (*efecto acantilado*) in telecommunication. It describes the sudden loss of digital signal reception of the TV signal where the digital signal suddenly disappears or "falls-off a cliff" instead of suffering a gradual loss or "roll off", as used to happen with the analogue TV. Lastly, a metonymy related to this productive conceptual metaphor is the term "earth", also "ground" in technology. It refers to the piece of the electric equipment connected to the ground, and is rich in different collocations. For instance, "earth resistance" (*resistencia de tierra*), "earth spring" (*resorte de puesta a tierra*), or "earth wire" (*hilo de tierra*).

Discussion

Although CMT provides a solid framework for the study of domain-specific mappings, we agree with Pérez-Hernández and Ruiz de Mendoza (2011: 138) that the "notion of domain needs to be explored in more detail, especially the questions of domain types and degrees of abstraction in metaphorical operations, … and the way in which source and target correspond". Both emerging technologies and new scientific developments need new lexical concepts, understood as those semantic units conventionally associated with linguistic forms (Evans, 2013: 73), so emerging scientific developments frequently borrow such semantic units from other fields, creating new metaphorical expressions. Along the paper we have explored certain domain types scientifically unrelated (Table 8), which show the different degrees of concreteness and abstraction involved in source and target correspondences. Thus, biology and genetics as source domains contain concepts at a higher or equal level of abstraction than their corresponding ones in the target domains (e.g. "barrenness", "consanguinity", "twin", applied to rocks and minerals), contrary to the general belief that the target is more abstract than the source. On the other hand, the lexical concepts "avalanche", "overflow", and "cliff" from earth sciences (Table 7), are not as abstract as their corresponding concepts in the target field of telecommunications.

Metaphor	Source domain	Target domain
ROCKS AND MINERALS ARE HUMAN BEINGS	biology, genetics, social sciences	Geology, Mineralogy
ROCK PROCESSES ARE PLANT PROCESSES	Agronomy	Geology
ROCK FORMATIONS ARE ARCHITECTURAL ELEMENTS	Architecture, building	Geology
IT LAYOUTS ARE ARCHITECTURAL/BUILDING DESIGNS	Architecture, building	Information technologies
IT TOPOLOGY IS A TREE	Agroforestry	Information technologies
ELECTRIC/ INFORMATION MOVEMENT IS WATER FLOW	Hydrology, hydrogeology	Information tech. Telecommunication
ELECTRONIC TRANSMISSION VARIATIONS ARE GEOLOGICAL FEATURES AND EVENTS	Geology	Telecommunication

Table 8. Cross-disciplinary mappings in science and technology.

Lakoff and Johnson's (1980: 3) belief that "our concepts structure what we perceive" has been confirmed as we discovered the patterns scientists use to structure new knowledge when thinking about science, including previous scientific concepts. Thus, the geology and hydrology domains provide a cognitive substrate for reasoning about electronic phenomena, in the same way that biology and sociology do it for geology. In specific contexts, the source domain is no longer activated, since the new term is endowed with additional specific attributes that were not present in the source. We may say that "the conceptual network has been extended by the analogical mapping and the vocabulary finds itself simultaneously associated with mapped counterparts", as Fauconnier (1997: 22) argued.

The way in which source and target correspond has been considered determinant when analysing the function of domain-specific mappings as conceptual categorisers. As the cognitive process of linking a specific domain with some other specific domain(s), as shown in Table 8, a conceptual metaphor may have a cognitive impact on our theoretical understanding of the target. This is the case of ROCKS AND MINERALS ARE HUMAN BEINGS, where the source-target relationship between the entities involved and their attributes implies abstract mental operations of the conceptual system, such as perception, categorization and inference. In this metaphor, the target domain draws very abstract concepts from social sciences, biology, and genetics, establishing a structural relationship with geological entities other than making rocks and earth phenomena more familiar and accessible to all (Kuhn, 1993: 539). This metaphor has become a constitutive element of its theoretical constructs and allows geoscientists to understand, give name and structure the realities involving the origin, composition, and evolution of rocks in terms of the source domains involved. It serves as a tool to reason about, organize and clarify geologists' theoretical understanding of rocks, proving to be a device for conceptualization and a prolific driving force for scientific language growth, thus highlighting a clear case of a theory-constitutive metaphor (Boyd, 1993: 486).

Boyd (1993: 486-490) argues that theory-constitutive metaphors are used when there is a high degree of analogy between the literal and the secondary subjects and, therefore, they can maintain their interactive qualities even though different authors along the time may introduce eventual variations. Thus, two other metaphors ELECTRIC/ INFORMATION MOVEMENT IS WATER FLOW (Table 6), and ELECTRONIC TRANSMISSION

MOVEMENTS ARE GEOLOGICAL FEATURES AND EVENTS (Table 7) may be considered as theory-constitutive metaphors, too. In these cases, there is not only a high degree of analogy between source and target metaphorical conceptualizations, but also a consistent framework for the analysis and development of the emerging field of electronics (Wacker, 1998: 361).

On the other hand, in cases three (Table 3) and four (Table 4), where Architecture and Building (A&B) is the source domain, the correspondences established between a common source and two target domains – Geology and IT – are based on visual perception, functional analogy and structural relationships (Figure 3). Kövecses' (2016: 12) recent definition of conceptual metaphor as "a systematic set of correspondences between two domains of experience" applies well in both cases of mapping relationships. These correspondences do not appear in isolation. They are quite productive in derived metaphorical expressions, showing how the corresponding mappings extend to frame different specific targets. For example, "dome", which constitutes a part of the vocabulary in Geology, is a lexical concept borrowed from architecture from which other lexical concepts derive (Table 3). The conceptual system facilitates functions such as perception, categorization, inference, and choice, to create new lexical units. Thus, the terms "salt dome", and "volcanic dome" reveal different types of dome. "Dome fold" describes a bend in the massif rock. In "dome crest", depicted in Figure 1, "crest" refers to the outstanding part on top of the rock summit known as "dome". Likewise, "window", which in IT refers to "a section of a screen", develops new lexical units such as "floating window", and "cascade windows" (Table 5). In Figure 3 we compare correspondences between the A&B source domain and the fields of Geology and IT, depicting not only the visual and functional relationships found, but also structural correspondences, where "one concept is structured in terms of another" (Lakoff & Johnson, 1980: 14). Structural metaphors are mostly found in IT, where the source (A&B) provides a structure to think about and understand technological concepts, which seldom occurs in geology transpositions. As can be seen in Figure 3, one specific source domain may provide the background for a varied set of correspondences for different target domains.

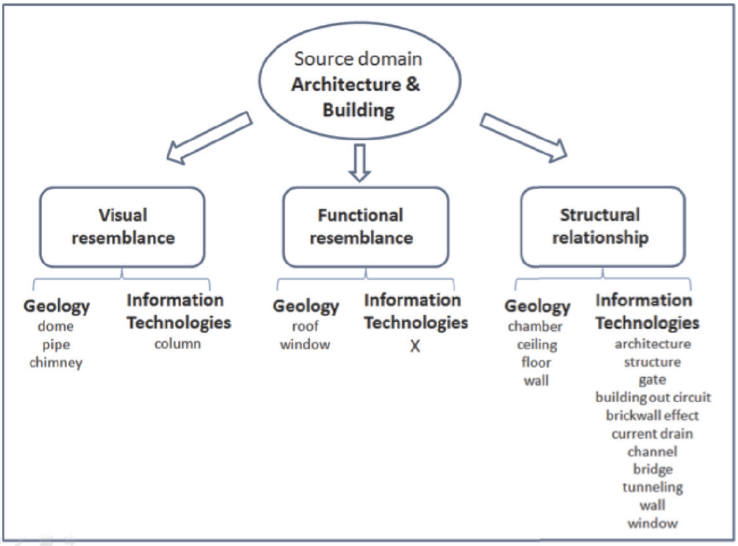

Figure 3. Correspondences from Architecture & Building onto Geology & IT.

Conclusions

The aim of this qualitative study has been to corroborate that cross-domain mapping conceptualizations regularly occur within science and technology resulting in the development of new terms both as part of conceptual metaphors and as independent lexical units. Focusing on the metaphorical vocabulary from the fields of Geoscience and Telecommunications Engineering, we have highlighted the different roles of the source domain in providing conceptual categorization for the target. We have argued that new technologies and scientific developments frequently borrow concepts from other scientific fields, which may be close to them or totally unrelated. In fact, a large amount of new vocabulary in the emerging technologies comes from older sciences, as has been shown in the case of IT mappings from earth sciences. In all cases of domain-specific mappings, homonymous terms in source and target domains are monosemic within their knowledge fields (e.g. "valley" in Geography and "valley" in Electronics).

Regarding the examples presented, we have observed that Geoscience is an important source domain for many of the metaphors in the area of IT and that between these apparently unrelated fields a number of deep analogies and parallelisms have been established. For example, in the creation of new metaphorical terms in both IT and Geosciences we have discovered other third areas in common, such as Architecture and Building or Agronomy and Agroforestry. From their vocabularies, it has been observed that the metaphorical structuring of concepts from one common source found in the two target fields is partial, according to the metaphorical expressions analysed. Thus, the evidence presented has confirmed that metaphor may be used not only to describe but to create new conceptual, mental spaces in science and technology because, when a metaphor is operational, scientists focus on a selection of features activating a new perspective to understand new concepts.

As postulated by Boyd (1993: 486), some metaphorical expressions constitute "an irreplaceable part of the linguistic machinery of a scientific theory". Although the existence of such theory-constitutive metaphors has been questioned, we have provided at least three possible examples according to Boyd's characterization (1993: 486-490): ROCKS AND MINERALS ARE HUMAN BEINGS, ELECTRIC/INFORMATION MOVEMENT IS WATER FLOW and ELECTRONIC TRANSMISSION VARIATIONS ARE GEOLOGICAL FEATURES AND EVENTS. The examples discussed corroborate the thesis that a metaphor can be a very productive organising mechanism in language as scaffolding for human creative thinking. Moreover, metaphors can provide the descriptive and explanatory elements that support formal definitions, as has been made explicit in the mappings in Tables 1-7. Therefore, the study confirms the power of metaphor as a tool for concept designation in science and technology, highlighting the different degrees of categorization involved in the building of new theories, concepts, and linguistic expressions. Further studies are needed in these and newer fields to corroborate the pervasive constitutive function of conceptual metaphor in science and technology theory development and to unveil the semantic roots of shared mental spaces between apparently unrelated specific fields.

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Pilar Durán-Escribano (PhD) is an Associate Professor at Universidad Politécnica de Madrid, lecturing EST and EAP to Mining and Geological Engineering. Her research interests include the analysis and the pedagogy of EST texts and academic genres, the application of CEFRL directives to EAP, and the study of metaphor in science. As member of the Research Group DISCYT, she has co-authored the *Bilingual Dictionary of Scientific and*

Technical Metaphors and Metonymies (Routledge, 2016), coordinating the areas of Geological Engineering and Physics.

Irina Argüelles-Álvarez (PhD) is an Associate Professor at Universidad Politécnica de Madrid. She lectures EAP at the School of Engineering and Telecommunication Systems. Her research areas cover the integration of technologies to enhance motivation in EST learning, and metaphor and metonymy in information technologies. As member of the Research Group DISCYT, she has co-authored the *Bilingual Dictionary of Scientific and Technical Metaphors and Metonymies* (Routledge, 2016), coordinating the areas of Electronics, and Telecommunication & Computing Engineering.

NOTES

[1] Research Project: *Bilingual Dictionary of Scientific and Technical Metaphors and Metonymies*, 2013-2015 (cf. Bibliography), Funded by Fundación Gómez Pardo (UPM) & Colegio de Ingenieros de Minas de Madrid. Participants: G. Cuadrado (P.I.), Co-Investigators: I. Argüelles, P. Durán, M-J. Gómez, S. Molina, J. Pierce, M-M. Robisco, A. Roldán & P. Úbeda.

[2] Searching for the use of "consanguineous" in reference to rocks, "parentage" was found. This metaphorical expression did not appear in any of the dictionaries consulted, but "parent mineral" and "parental rocks" did. It was obvious that this new linguistic expression formed part of the same conceptual metaphor as the other metaphorical expressions, so it was incorporated into Table 1. This type of finding has frequently occurred along our research.

Appendix 1

Name	Features	Entries
Bilingual Dictionary of Scientific and Technical Metaphors and Metonymies Routledge (2016)	11,000 Spanish-English & 12,125 English-Spanish metaphorical terms.	23,125
Dictionary of Mining, Mineral, and Related Terms (1967/1990)	150,000 definitions of technical terms and expressions related to mining, geology, metallurgy, and mineralogy, from the entire English-speaking world.	55,000
McGraw-Hill Dictionary of Scientific and Technical Terms (2000)	125,000 definitions of 104 fields related to science and technology	110,000
New Polytechnic Dictionary of Spanish & English Language (1988)	All engineering and related fields:	
	Volume I English/Spanish –	275,000
	Volume II Spanish/English –	300,000
Oxford Dictionary of Geology & Earth Sciences (2003/2008)	Earth science terms and definitions, web linked.	6,250

Diccionario de electrónica,Informática y Energía Nuclear (1999)	English-Spanish – Spanish-English	29,000
Desktop Encyclopedia of Telecommunications (2002)	Over 300 articles 3-5 pages long 1,249 pages	
Encyclopedia of Networking & Telecommunications (2001)	1,400 networking concepts 1,447 pages	
Diccionario de Informática, Telecomunicaciones y Ciencias Afines (2004)	English-Spanish – Spanish-English 6,000 definitions	83,000

Table 9. Referential corpus for the analysis of metaphorical terms.