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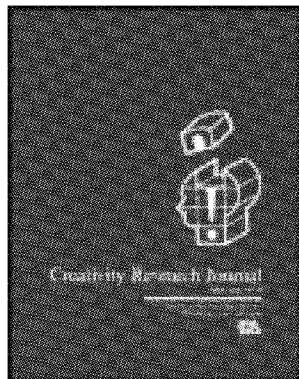


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The Role of Metaphorical Thinking in the Creativity of Scientific Discourse

Maria-Jose Sanchez-Ruiz ^a, Manuela Romo Santos ^b & Juan Jiménez Jiménez ^c

^a Lebanese American University, Lebanon

^b Autonomous University of Madrid, Spain

^c National University of Distance Learning (UNED), Spain

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The Role of Metaphorical Thinking in the Creativity of Scientific Discourse

Maria-Jose Sanchez-Ruiz

Lebanese American University, Lebanon

Manuela Romo Santos

Autonomous University of Madrid, Spain

Juan Jiménez Jiménez

National University of Distance Learning (UNED), Spain

This article critically reviews the extant literature on scientific creativity and metaphorical thinking. Metaphorical thinking is based on a conceptual transfer of relationships or mapping, from a well-known source domain to a poorly known target domain, which could result in creative outcomes in sciences. Creativity leads to products that are deemed to be novel and original as well as useful and adaptive. After reviewing the concepts of metaphor and analogy and the types of metaphor identified in the literature, the relationships traditionally theorized between metaphors and creativity from different scientific disciplines were discussed, with special focus on the psychology of creativity. The empirical study of the links between creativity and metaphors can contribute to a better understanding of the scientific process. Promising lines for future research are advanced, such as the exploration of the relationship between the presence of certain types of metaphors in scientific theories and the level of creativity of such theories.

There have been a number of studies on the relationship between metaphors and creativity. Some of the research has focused on exploring the role of metaphors in poetry (Blasko & Merski, 1998) or examining metaphor comprehension in children (Seitz, 1997), assuming that the understanding and use of metaphorical thinking equals creativity.

Less research has been conducted to clarify the role of metaphors in the formulation of scientific theories (Miller, 1996), and empirically testing whether the use of metaphors has strong benefits for creativity in sciences. The original contribution of this review is that it critically examines the (a) impact of metaphors in the

formulation of scientific theories and (b) repercussions for the creative process in sciences, especially from a psychological perspective, while identifying areas of improvement in previous literature. Moreover, this article provides guidelines for future research on the relationship between metaphorical thinking and creativity in sciences and suggests possible factors affecting such a relationship.

The first step in examining the link between creativity and metaphors is clearly defining both concepts. What distinguishes creativity from other human activity is the special characteristics of the creative products. Creative products should be unique and demonstrate novelty and value simultaneously, to be considered genuinely creative. To date, a variety of definitions of creativity has been proposed and reviewed (Sanchez-Ruiz, 2009). Instead of *novelty*, some authors use the terms *originality*, *surprise*, or *change*, and the term *value* is, at times, substituted by *utility*, *adaptation*, or

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Correspondence should be sent to Maria-Jose Sanchez-Ruiz, Lebanese American University, School of Arts and Sciences, Byblos, Lebanon (P.O. Box: 36). E-mail: maria-jose.sanchez-ruiz@lau.edu.lb

TABLE 1
Examples of Definitions of Creativity Based on the "Novelty" and
"Value" Criteria

<p>"Creativity is the ability to come up with ideas or artefacts that are <i>new, surprising and valuable</i>. 'Ideas' here include concepts, poems, musical compositions, scientific theories, cookery recipes, choreography, jokes—and so on. 'Artefacts' include paintings, sculptures, steam engines, vacuum cleaners, pottery, origami, penny whistles—and many other things you can name" (Boden, 2004, p. 1).</p> <p>"<i>Creative thought or behaviour</i> must be both novel-original and useful-adaptive" (Feist, 1998, p. 28).</p> <p>"Bringing something into being that is <i>Original</i> (new, unusual, novel, unexpected) and also <i>Valuable</i> (useful, good, adaptive, appropriate)" (Ochse, 1990, p. 2).</p> <p>"Psychologists have reached the conclusion that creativity must entail the following two separate components. First a creative idea or product must be original. ... However, to provide a meaningful criterion, originality must be defined with respect to a particular sociocultural group. What may be original with respect to one culture may be old news to the members of some other culture. ... Second, the original idea or product must prove adaptive in some sense. The exact nature of this criterion depends on the type of creativity being displayed" (Simonton, 1999, pp. 5–6).</p> <p>"Creativity is the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)" (Sternberg & Lubart, 1999, p. 3).</p>

Note. Adapted from Batey and Furnham (2006).

accuracy (see Table 1). Overall, there is currently a wide consensus among researchers that creativity is a human activity that generates new and valuable products, ideas that were originated in the '60s (e.g., Bruner, 1962; see Runco & Jaeger, 2012, for a review).

Csikszentmihalyi (1996) argued that characteristics of creative products depend on the sociocultural context. He suggested that the novelty of a thought cannot be estimated following a few criteria, and its value cannot be determined until it surpasses social evaluation. Therefore, scientific creativity refers to a collective activity that is socially and culturally determined and leads to the generation of some kind of scientific product (e.g., a theory of the world, a specific research method, an assessment instrument, a technological tool). This product should satisfy both criteria, namely novelty and value. Scientific novelty emerges from overcoming traditional theories, the discrepancy among accepted premises by the context, and the formulation of new paradigms. The value of scientific theories depends on the product adjustment and adaptation to reality, as well as its explicative validity (e.g., in biology), and its capacity to solve specific problems (e.g., in technology).

METAPHORS AND ANALOGIES

The currently accepted definition of metaphors in linguistics follows from Lakoff's (1993) conceptual

theory. According to this theory, the main function of metaphors is to facilitate the understanding of an abstract or disorganized domain on the basis of a familiar or better-structured domain (Lakoff & Johnson, 1980). For instance, personification is a common type of metaphor that allows one "to use insights about ourselves to help us comprehend such things as forces of nature, common events, abstract concepts, and inanimate objects" (Lakoff & Turner, 1989, p. 72).

Technically, a metaphor is defined as a transference of conceptual relationships (*mapping*) from a specific domain, or *source*, to another domain, or *target* (Lakoff, 1993). The result of this transference of meanings between different domains of knowledge is a new conceptual organization of the target domain in terms of the source domain. There are various other linguistic definitions of metaphors, but they all coincide in their conceptual structure. For example, Black (1993) defined metaphor as the application of a set of "associated implications" (p. 28) or related inferences from a "main subject" which is well-known, to the "subsidiary subject" (p. 35), which is poorly known.

However, this correspondence between domains is not perfect, but partial or incomplete (Bailer-Jones, 2002; Lakoff & Turner, 1989). There are certain properties of the source domain that are ignored because they do not fit the target domain. Richards (1936), pioneer author in the linguistic analysis of metaphors, referred to "tension" (p. 124) to describe this impossibility of a literal transference of semantic relationships between two domains, namely "topic" (p. 72) and "vehicle" (p. 96).

Furthermore, analogy is a concept closely related to metaphor. In the past, Aristotle defined analogy as a particular type of metaphor. According to the philosopher, although metaphors state a relationship between two terms, where the first is identified with the second (A is B), analogies state a relationship between four terms, so that the first is to the second as the third is to the fourth (A is to B as C is to D). However, the present use of the term *analogy* is problematic, due to an extant terminological confusion in the literature.

A number of authors have suggested various criteria to differentiate between metaphor and analogy. One of those authors is McReynolds (1990), who suggested that metaphor is normally used to emphasize identification between two domains, and analogy is used more commonly to indicate similarity of two domains, but at the same time recognizes differences between them. Nevertheless, Richards' (1936) concept of metaphorical "tension" (p. 124) suggests that the identification in a metaphor refers to the specific linguistic expression chosen by the author, but not to the meaning, because metaphor cannot imply a complete identification at a conceptual level.

In practical terms, it is not possible to establish a clear limit between metaphor and analogy, especially

when reviewing the scientific literature of the two concepts. In the literature, both terms are normally interchangeable, or analogy is considered as a specific type of metaphor (Pérez-Bernal, 2007; Romo, 1997). In light of this, McReynolds (1990) reached the following conclusion: "In practice, the distinctions among similes, metaphors, models, and analogies are not always clear-cut. There is a growing tendency to employ the word 'metaphor' as a generic term for all of the above dyadic expressions" (p. 136). In other occasions, definitions of both terms are extremely similar. For instance, Johnson-Laird (1989) defined analogy as a resource that allows explaining a problematic domain of knowledge (target), through a familiar domain of knowledge (source), in clear correspondence with the definition of metaphor proposed by Lakoff (1993).

TYPES OF METAPHORS AND THEIR APPLICATIONS

There are different classifications of metaphors. This review focused on the main typologies proposed from a linguistic perspective. First, the conceptual theory classifies metaphors as *new* or *conventional* (Lakoff & Johnson, 1980; Lakoff & Turner, 1989), depending on their frequency of use within the speakers' community. When new metaphors appear, they allow attaching new meaning to experiences and the outside world. When a metaphor is to be part of a linguistic repertoire within a community, its use is generalized and it becomes conventional: "At the conceptual level, a metaphor is conventional to the extent that it is automatic, effortless, and generally established as a mode of thought among members of a linguistic community" (Lakoff & Turner, 1989, p. 55).

Another linguistic typology is the one proposed by Werth (1994), who discriminated among metaphors based on their extension within the discourse. According to Werth, metaphors can be found not only in specific sentences, but also in the discourse as a whole. Some metaphors are located at particular points of the discourse and function at a superficial level; those are called *micro-metaphors*. There is another type of metaphor that is less explicit and localized, but works at a deeper level, which is called a *mega-metaphor*. Mega-metaphors act as a subliminal message that continues throughout the entire discourse and helps by providing it with coherence. For instance, stemming from the Cognitive Revolution of the 1960s, neuroscientists and cognitive psychologists adopted the reference to computers as a mega-metaphor to explain cognitive processes and neurological functions (e.g., the information processing model to memory; Gigerezner & Goldstein, 1996).

Perhaps a more fruitful term in discourse analysis is the "conceptual metaphor," which was suggested by Charteris-Black (2004, p. 180) and refers to the deep metaphorical concept underlying superficial metaphorical expressions. In the same discourse, a variety of metaphors interconnected and explained through the same conceptual clue can be found, which is essential to the understanding of such metaphors.

Another metaphor classification relevant to the research on the role of metaphors in science is the one proposed by Boyd (1993), who distinguished between *pedagogical* and *constitutive* metaphors. Pedagogical metaphors play a didactic role in the communication of scientific theories and facilitate their understanding, but they neither play a crucial role in the specifications of the theories nor do they contribute to the development of such theories. This kind of metaphor is especially useful for educational purposes and simplifies the scientific discourse favoring its accessibility to students and allowing its popularization in general (Parkinson & Adendorff, 2004). On a different note, constitutive metaphors are an irreplaceable piece in theory formulation, because they are aimed at defining new concepts (e.g., black hole, genetic code, mother cell). Constitutive metaphors are those "which scientists use in expressing theoretical claims for which no adequate literal paraphrase is known" (Boyd, 1993, p. 486).

Gruber, Bödeker, and Wallace (2005) proposed the notion of "images of wide scope" (p. 254) not as mere expressive devices, but as figures of thought that are irreplaceable constituents of the theory. This notion has been collected in other works following the "evolving systems approach" (p. 49) of Gruber. For example, Osowski contended that the images of wide scope are not only wide but deep, in that "they direct the development of theories, in this sense functioning as regulatory schemas," and related them to the concept of theory-constitutive metaphors of Boyd (Osowski, 1989, p. 128). In his work about William James, Osowski (1989) stated that his well-known metaphor of "stream of thought" plays the same role as Gruber's "images of wide scope" (p. 129), including the metaphors of the train, chain, path, and current, used to explore the notions of continuity, change, and connection. Gruber's idea of images of wide scope can also be related to the mega-metaphors that Werth (1994) argued for, which are pervasive metaphors located at the deep roots of certain scientific discourses.

McReynolds (1990) suggested that metaphors in science have three functions: describe, explain, and persuade. The descriptive function has a didactic and communicative utility, as in the pedagogic metaphor of Boyd (1993). The explanatory function aims at solving theoretical problems allowing the analysis of relevant phenomena from new viewpoints, as in the constitutive

metaphors of Boyd. Finally, the persuasive function of the metaphor has no equivalent in Boyd's theory, but it plays a psychological role. The aim of this function is to convince; its goal is selling the scientific discourse to a given audience through rhetoric. One strategy in persuasion is to associate the defended ideas with others that are held by prestigious authors. Another strategy is the use of metaphor as a literary resource, trying to charge the ideas supported emotionally. Both strategies aim at promoting the acceptance of the ideas communicated among scientists or laypeople, regardless of the intrinsic value of such ideas.

The use and abuse of persuasive metaphors, especially within social disciplines, was reported by the physicists Sokal and Bricmont (1998) in their book, *Intellectual Impostures*. These authors argued that social sciences are riddled with inappropriate use of metaphors from natural sciences, often to give the discourse a varnish of prestige discourse and to deviate the attention from possible conceptual and/or empirical limitations of such discourse. Sokal and Bricmont did not argue against establishing analogies between two distinct disciplines and recognizing that analogical thinking can be productive in terms of theory development. However, the authors stated that abuse of scientific terminology reflects in "importing concepts from the natural sciences into the humanities or social sciences without giving the slightest conceptual or empirical justification" (Sokal & Bricmont, 1998, p. 4).

In the literature, metaphorical and analogical thinking have been frequently associated with creativity (e.g., Casakin, 2007; Minervino & Oberholzer, 2007). Much of the early work on creativity research underlines the idea that associative thinking is in the roots of creativity and that the combination of disparate elements could lead to creative products (Mednick, 1962). Romo (1997), from the psychology of creativity perspective, described analogical thinking as the transference of meaning from one domain to another involving an infrequent use of the concepts, whereby literality is lost and a new meaningful holism is generated. In general, the conceptual distance between the elements mapped in an analogy is associated with novelty or originality because that distance often produces less obvious and more creative comparisons (Barnett & Ceci, 2002; Holyoak & Thagard, 1995).

However, in light of the previous review, it is evident that not all types of metaphors can be a source of creativity and scientific progress. Although new and constitutive metaphors can lead to creativity in science, conventional or pedagogical ones may not—using Lakoff and Turner's (1989) and Boyd's (1993) classifications, respectively. Furthermore, persuasive metaphors could be an obstacle to the development of some sciences. Thus, future research investigating the

relationship between metaphors and scientific creativity could benefit from incorporating the type of metaphor as a key factor in their study designs.

RESEARCH ON THE RELATIONSHIP BETWEEN METAPHOR AND SCIENTIFIC CREATIVITY

The association between the use of metaphors and the level of creativity in scientific endeavors has been profusely discussed in a number of disciplines, including philosophy, linguistics, and psychology. From the philosophy of science approach, the analysis of metaphors in science is controversial. Some authors have considered that any kind of knowledge is ultimately a metaphor, because it represents a nonliteral interpretation of reality. Dissidents of this view state that this definition of metaphors is excessively wide. For example, Alcíbal (1999) argued that the use of abstract schema, as in geometry or mathematics, to represent concrete reality can be considered as metaphorical, as extrapolating previous models from a well-known domain to a new one. On the contrary, Rivadulla (2006) challenged this approach, indicating that not everything in science should be referred to as a metaphor:

It is very easy to go from recognizing the use more or less widespread of metaphors in science, to affirm that everything in science is a metaphor and our understanding of the word is mostly metaphorical. But hey! science, and in particular physics, is quantitative; therefore, it is difficult to consider physics to be essentially metaphorical or qualitative. (p. 200)

From a linguistic approach, Veale (2006) claimed that metaphor and analogy are processes closely linked to the linguistic change: They are mechanisms that can produce new word meanings and have the potential to modify the way in which individuals perceive and represent the world around them. This idea is applicable not only to the popular knowledge, but also to the scientific disciplines. However, neither philosophy nor linguistics alone can comprehensively tackle the empirical study of the relationship between metaphor and scientific creativity. Finally, the main contributions of this relationship belong to the psychology mainstream, although such contributions are normally limited to the theoretical level.

From the approach of psychology of creativity, the use of metaphors has a fundamental role within the creative thought processes. For example, according to the combinatory hypothesis of creativity, the association between independent conceptual frameworks is the main source of creative inspiration (Koestler, 1964; Mednick,

1976). This hypothesis postulates that the more distant the associated concepts are, the more productive the metaphor will be in terms of creative insight generation.

De Mink (1995), also at a theoretical level, highlighted the causal role that metaphors play in the creative-thought and problem-solving processes, through conscious or unconscious ways. According to this author, a successful metaphor can generate more enriching ideas than a logical explanation. De la Fuente and Minervino (2004), who did not discriminate between metaphors and analogies, postulated that establishing interdomain analogies are essential mechanisms for creativity in any discipline or domain. These authors argued for the idea that an interdomain analogy occurs when "two specific situations or domains are organized on the bases of related systems and comparable roles" (p. 193). Along the same lines, Markman, Wood, Linsey, Murphy, and Laux (2009) pointed out that certain problems become impossible to solve using traditional strategies, and people are forced to use their previous knowledge to establish analogies. The authors suggested that the development of individuals' analogical thinking skills could enhance their creativity.

The relationship between metaphor and creativity has been also discussed in the scientific arena. For instance, Johnson-Laird (1989) stated that scientific innovation and the solution of scientific problems often occur because of analogical thinking. Furthermore, Miller (1996) stressed that metaphors are a critical piece of scientific creativity because they can generate new understandings of reality, which can, in turn, transform into new theoretical models. In addition, metaphors can improve the organization of empirical data and, ultimately, facilitate scientific progress. Miller illustrated these ideas by citing a number of scientists who used metaphors in physics: Niel Bohr, Albert Einstein, Enrico Fermi, Werner Heisenberg, James Clerk Maxwell, Abdus Salam, Steven Weinberg, and Hideki Yukawa.

Some advocates of the beneficial role of metaphors in scientific research highly recommend their use, as in the case of Rosenman (2008), who reflected on the importance of metaphors within the clinical practice. According to this author, although many professionals try to avoid the use of metaphors, these are present in a wide number of medical concepts, not only related to illness but also to the normal functioning of the organisms. From a clinical psychology approach, the use of metaphors is also considered beneficial within the process of psychotherapeutic practice, whereby the therapist would use this linguistic element to introduce new and valuable insights into the patient's current understanding of his or her own condition, and to develop new and adjusted behavioural patterns (Witztum, Van der Hart, & Friedman, 1988).

Finally, the use of metaphors could be an effective strategy in problem-solving. Metaphors can be an instrument to direct the route toward a resolution. Finding a resolution toward a scientific debate requires that a situation be addressed in different lights and information be extrapolated from other fields to the target situation. In this way, metaphors can be used here to add novelty and value to the solution (e.g., Casakin, 2007).

It can be concluded that the theoretical association between metaphors and creativity is a constant in the literature of creativity psychology, and it has become a widely accepted idea. Therefore, the majority of creativity researchers assume the existence of a close relationship between the two constructs, which is often considered of a causal nature. On occasions, erroneous identifications of the two concepts can be found in the literature, as in the case of Shibles (1979), who defined creativity as the ability of generating metaphors, thus confusing the two terms.

However, very few psychological studies have focused on the role of metaphors in the scientific discipline, and those few were often retroactive, based on anecdotic evidence, and/or only addressed the issue at a descriptive level. One of the studies attempting to study the phenomenon of metaphors in science descriptively was conducted by Dunbar (1997), who recorded the content of molecular biology research meetings and found different types of metaphors in the scientific discourse (an average of 6.1 per meeting), whereby those metaphors with biological content were more frequent (proximal metaphors) than those with non-biological content (distant metaphors). Almost half of the metaphors identified by Dunbar showed didactic purposes and were used to explain specific methodological questions, although he also detected metaphors specifically formulated in relation to the hypothesis and research design. From a linguistic perspective, Low (2008) studied the presence of metaphors in the social science discourse and found that there was a 9–15% metaphorical lexicon in the scientific reviews analyzed.

Other examples are McReynolds' (1990) review of metaphors used in psychology of motivation; Gould's (1993) analysis of the functions of metaphors in Darwin's ideas; the study conducted by Gentner, Brem, Ferguson, and Wolff (1997) on the metaphorical content of Kepler's work; and the cognitive case studies of Gruber about Darwin and Osowski about James (both in Wallace & Gruber, 1989).

In sum, the majority of the research that focuses on the relationship between metaphors and scientific creativity is mainly theoretical, and the few empirical studies conducted investigate the metaphors frequency of appearance of metaphors in specific sciences and particular examples or qualitative analysis of case studies, which results can be difficult to generalize.

FUTURE RESEARCH AND IMPLICATIONS

There is a need for more rigorous and systematic research investigating the role of metaphors in the scientific creativity processes. To this respect, the idea is that there are three key steps to follow. First, it is necessary to demonstrate empirically the association between both variables, metaphor and scientific creativity, to rule out that the presence of metaphors in the scientific discourse could be a sterile phenomenon unrelated to creativity, or a mere evidence of the importance of metaphors in human discourse in general (a constant such as language grammar).

Second, it is crucial to analyze the influence of metaphors in the development of different scientific disciplines, considering not only its positive dimensions, but also possible negative effects. The existence of infertile metaphors in the history of science is well-known, and some of them had blocked the development of new models for long periods. For example, Aristotle's idea of substance *horror vacui* ("fear of emptiness") stopped the acceptance of Torricelli's explanations about atmospheric pressure (Romo, 1997).

Similarly, the use of metaphors with persuasive purposes could negatively interfere with the development of certain disciplines, in particular social sciences (Sokal & Bricmont, 1998), because persuasion often influences the acceptance of ideas through criteria completely detached from the scientific method. Even if the analysis is limited to productive metaphors, other factors may have a greater impact on scientific creativity, thus overshadowing the importance of such metaphors. Therefore, the presence of metaphors in the scientific discourse could be a secondary phenomenon in scientific progress, which could even damage the scientific progress under certain circumstances. It is essential, then, to identify the type of metaphor studied because, as noted earlier, the relationship between metaphorical thinking and scientific creativity can vary according to the type of metaphor being studied.

The argument that the use of metaphors boosts scientific creativity is still too broad and imprecise. For this argument to be valid, as a third step, research needs to determine which characteristics allow the efficiency (in terms of creativity and scientific progress) of a metaphor within current sciences. This review has identified some of those characteristics by looking at the different classifications of metaphors.

To summarize, when researching the issue of metaphors in scientific creativity, there are some clear gaps to be filled and assumptions made on shaky grounds. One of the crucial questions researchers need to answer is: Is there any relationship between the use of metaphors in scientific theories and the level of creativity of such theories? To answer this question, the first step

could be then to select a series of representative theories within each subfield of a scientific discipline; the second step would be to identify rigorously the type of metaphor appearing in the theory following particular criteria; and the third step would be to evaluate the creativity of the theory objectively.

Once the hypothesis is tested and supported, then the challenge will be to test whether the development of individuals' metaphorical skills does, in fact, enhance scientific creativity. This practical aim requires the application of experimental research designs to natural contexts, where daily scientific work is taking place and creativity can emerge at any time.

Research on the relationship between metaphorical thinking and creativity should explore systematically and empirically, such a relationship in a variety of scientific discourses. This will allow comparisons among scientific disciplines in terms of the fecundity of different types of metaphors in each science. In light of the findings obtained from those studies, other types of studies can follow. For instance, investigating the effects of enhancing metaphorical thinking on undergraduates' scientific creativity in different domains can have practical implications for the educational technology, and can ultimately help develop and implement training programs and specific techniques aiming to promote scientific creativity. It is worth noting that, even if the existence of a relationship between creativity and the use of constitutive metaphors is demonstrated, it is crucial to test the causality of such a relationship, ruling out, when possible, the influence of confounding variables.

Boyd's (1993) classification of metaphors (i.e., pedagogical and constitutive metaphors) shows conceptual clarity and empirical applicability, and thus can be used to study the relationships between creativity and the scientific discourse. In particular, a fruitful line of research could aim at determining whether scientific theories using constitutive metaphors are rated as more original, valuable, productive, and ultimately creative among experts from the specific study domain, when compared to other types of metaphors.

CONCLUSIONS

This study presented a review of the literature on the classification of metaphors and their application, as well as the links between metaphors and scientific creativity from different knowledge areas, especially psychology. Some of reasons underlying the idea of metaphors as tools to assist scientific progress is based on the traditional combinatorial hypothesis of creativity (e.g., Mednick, 1976), the idea of transforming existing data into something new (Miller, 1996), and the usefulness

of metaphors in problem solving (Markman et al., 2009). A critical review of earlier research has helped offer informed recommendations for future research. One of those recommendations is the examination of the links between metaphorical thinking and creativity empirically and systematically to further comprehend the scientific process. This review suggested that one promising line of research is the investigation of the presence of certain metaphors in scientific theories and the level of creativity of such theories. Also, other studies could focus on analyzing the role of metaphorical thinking in the development of a variety of scientific disciplines. On a more pragmatic note, research can explore the possibility of developing programs aiming at cultivating metaphorical thinking to enhance science education.

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