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Use of the "Tree" Analogy in Evolution Teaching by Biology Teachers

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Abstract This work discusses the use of Darwin's 'Tree of Life' as a didactic analogy and metaphor in teaching evolution. It investigates whether biology teachers of pupils from 17 to 18 years old know Darwin's text 'Tree of Life'. In addition, it examines whether those teachers systematically employ either the analogies present in that text or other analogies between the tree and evolution, and whether they adopt a specific methodology for teaching with analogies and metaphors (A&M). The academic training of teachers regarding use of A&M is review briefly. A diagnostic study was carried out with biology teachers in a public school in the town of Contagem in the state of Minas Gerais in Brazil. The data were obtained through direct observation, questionnaires and a focus group. The teachers pointed out in the questionnaires that some details of Darwin's analogy are utilized as a resource. However, analysis of the data indicates that the 'Tree of Life' text is not known or utilized in class. At the same time, the teachers state that they use aspects of the tree as a didactic resource to teach evolution and that its use facilitates the learning of content. The teachers have little knowledge of specific methodologies of teaching with analogies and metaphors, revealing that their training is incomplete in this area.

The affinities of all of the beings of the same class have sometimes been represented by a great tree. I believe this simile largely speaks the truth. (Darwin 1859, p. 129).

1 Introduction

Although affinities between organisms of the same class or group had been illustrated by using big trees before the publication of On the Origin of Species by Means of Natural Selection (hereafter, *Origin of Species*) by Charles Darwin in (1859), a clear and conscience development of analogical relations between a tree and life was first found in this publication. The present article focuses on these relations, which make up the text referred

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to, as the Tree of Life. It is good to note that Darwin doesn't use the Tree of Life as a title for any publication, chapter or section. It appears in the here quoted fragment where he develops the mentioned analogies.

> The affinities of all the beings of the same class have sometimes been represented by a great tree and I believe this simile largely speaks the truth. The green and budding twigs represent existing species; and those produced during each former year may represent the long succession of extinct species. At each period of growth all the growing twigs have tried to branch out on all sides, and to overtop and kill the surrounding twigs and branches, in the same manner as species and groups of species have tried to overmaster other species in the great battle for life. The limbs divided into great branches, and these into lesser and lesser branches, were themselves once, when the tree was small, budding twigs. Now, this *analogy* (our emphasis) of the former and present buds by ramifying branches may well represent the classification of all extinct and living species in groups subordinate to groups. Of the many twigs which flourished when the tree was a mere bush, only two or three, now grown into great branches, yet survive and bear all the other branches; so with the species which lived during long-past geological periods, very few now have living and modified descendants. From the first growth of the tree, many a limb and branch has decayed and dropped off; and these lost branches of various sizes may represent those whole orders, families, and genera which have now no living representatives, and which are known to us only from having been found in a fossil state. As we here and there see a thin straggling branch springing from a fork low down in a tree, and which by some chance has been favored and is still alive on its summit, so we occasionally see an animal like the Ornithorhynchus or Lepidosiren, which in some small degree connects by its affinities two large branches of life, and which has apparently been saved from fatal competition by having inhabited a protected station. As buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all sides many a feebler branch, so by generation I believe it has been with the great ***Tree of Life*** (our emphasis), which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications. (Darwin's description of the 'Tree of Life' in *On the Origin of Species by Means of Natural Selection*—1859, pp. 129–130).

Throughout the text, Darwin developed an explicit comparison between living beings and the development and morphology of a tree. From this comparison came the great 'Tree of Life' metaphor.

Found in various types of texts, analogies and metaphors (A&M) were for a long time seen as figures of speech with no cognitive or heuristic role. However, studies published in the last five decades indicate that analogies and metaphors do have an educative role. They are used when the writer wishes to facilitate the accommodation of content, theories, ideas and data, be that in science or even in everyday language. Hoffmann and Scheid (2007) explain that 'analogy doesn't presuppose symmetric equality, but a relationship used for the purpose of clarifying, organizing and evaluating the unknown commencing with the known'.[1]

In class, biology teachers frequently establish relationships of similarity. However, studies have shown that use of A&M in teaching does not always involve clear methodologies as teachers are often unaware of them. These relationships frequently and spontaneously arise when teachers attempt to relate new knowledge to something familiar to the pupil as a means of facilitating understanding.

This study attempted to determine whether teachers of biology, working with pupils aged 17 or 18, know Darwin's text involving the 'Tree of Life', and whether they systematically and consciously employ the analogies present in that text or other analogies between a tree and Evolution as a teaching methodology.

[1] The authors' translation of an original text in Portuguese.

2 Analogies and Metaphors

2.1 Concepts

There are many explanations of analogy and metaphor. For example, Abbagnano (1999) suggested the following[2]:

> *Analogy*: This term has two fundamental meanings: the first is the exact and restricted meaning extracted from the mathematics (equivalent to proportion) of equality of relationships; the second meaning is the probable extension of knowledge by the use of generic similarities to assist in making connections between different situations (Abbagnano 1999, p. 55)
> *Metaphor*: Transference of meaning. Aristotle said: The metaphor consists in giving something a name that belongs to another thing: a transference that can be carried out from one species to another or based on an analogy (Abbagnano 1999, p. 667)

In discussing evolution, it is common to use the noun 'analogy' in a biological sense, wherein similarity of structure suggests similarity of function, such as the wings of insects and birds. This application of the term, though legitimate and important, is not used in this research.

According to Duit (1991), Analogies and Metaphors are comparisons between distinct domains. In this research, the two terms are distinguished by assuming that, when spoken by a teacher or written in a textbook, *analogies explicitly state* the compared aspect of one domain, while *metaphors do not state the comparison explicitly*. The same approach is adopted by Treagust et al. (1992). The term 'target' is used for the comparative domain to be learned and 'vehicle' for the domain that is already known and which is used to establish the comparison.

In addition to adopting Duit's approach regarding A&M, in this study the notion of 'Conceptual Metaphor' developed by Lakoff and Johnson is equally important: 'the thought processes are in large part metaphorical and the human conceptual system is metaphorically structured and defined' (Lakoff and Johnson 2002, p. 48).[3] Beyond questions of language, the term Conceptual Metaphor suggests a system of conceptions that implicitly define our ways of understanding the world and relating to it, guiding our actions, perceptions and concept development, sometimes altering how the individual sees, thinks and acts when faced with the domains which contain the metaphor. As an example, we cite the Conceptual Metaphor "time is money". In this metaphor, there is a conceptual system characterized by notions such as 'having time', 'losing time', 'wasting time', 'giving time' and 'saving time', among others.

However, Lakoff and Johnson do not distinguish between everyday contexts and scientific ones. On the contrary, they indicate that so-called pure intellectual concepts, such as those associated with the term 'scientific theory', are frequently—perhaps always—based on physical and/or cultural metaphors.

Nagem (1997) proposes four types of analogy: 'structural'—the analogy compares two structures with possible similarity in form; 'functional'—there is a comparison between functions; 'zoomorphic'—the analogy attributes characteristics of animals to objects and phenomena; and 'frozen'—the terms define the phenomenon, that is, the analogy is considered a synonym.

[2] Abbagnano's (1999) concepts of analogy and metaphor were translated by the authors of this paper from the original text in Portuguese.

[3] The translation to English for the Lakoff and Johnson (2002) quotation was done by the authors of this paper from the version published in Brazil in 1992. The original book was published in English in 1980.

Frozen analogies are equivalent to a Conceptual Metaphors. They can also be considered 'dead' in that they refer to metaphors or analogies which are so deeply rooted in the vernacular that do not have a novel character. In this aspect the *vehicle* includes the concept of the *target*, making them practically synonymous.

2.2 Analogies, Metaphors and Cognition

Initially considered mere linguistic ornaments, analogies and metaphors have gained cognitive status in recent decades. Cachapuz comments on their use in science teaching:

> … analogies and metaphors may be an epistemological necessity since, along with the image that is associated with them, they can be powerful aids to cognition and in this sense are important tools in pupils' learning (Cachapuz 1989, p. 118).[4]

They can be considered 'learning facilitators' since they establish relationships between a concept that is already known, the vehicle, and new knowledge, the target, enabling better understanding and accommodation of the new idea. As Soares et al. expressed it,

> The use of analogies as a didactic resource is justified in that it enables the pupils to progress from the problem (a lack of comprehension of scientific concepts presented in the classroom), bringing them closer to the solution (understanding the new content). (Soares et al. 2008, pp. 37–38).

Polya (1995) describes a heuristic model which involves the following stages: understanding of a situation; developing a symbolic representation of it; establishing relationships with similar situations; executing a plan to resolve the situation and finally evaluating it.

For the stage where relationships are established, Polya suggests that the pupil can use analogical thinking, allowing him to reach a conclusion, based on an analogy using his current knowledge as the reference point.

Thus, by using analogical reasoning, pupils are able to stimulate and develop their cognitive skills thereby contributing to their scientific education. They can progress from just remembering content to developing cognitive abilities that involve more than simple memorization. In this way, A&M can expand cognitive perspective by facilitating heuristic procedures as Nagem (1997) proposes.

Therefore, by providing more than a simple relationship of similarity between distinct domains, the use of analogies can be considered a cognitive process which strengthens a mental structure. They are generators of a type of reasoning ('analogical reasoning') that is established by means of comparisons between different domains, and so contribute not just to learning but also to creative and innovative activity.

Ferry (2008), based mainly on Mól (1999), refers to authors who recognize this analogical cognitive process, and establishes models to determine when it takes place. The authors Ferry mentions include Clement (1993), Borges (1997) and González (2005).

According to Ferry, González, for example, states that analogical reasoning is made up of two processes. The first provides access to the vehicle, while the second involves extrapolation or establishing comparisons between relevant information between vehicle and target. In González' view, the fundamental step in analogical reasoning is the extrapolation process since this process finishes with the transfer of knowledge and learning.

[4] Translations of texts from Cachapuz (1989), Polya (1995), Soares et al. (2008) on this page were undertaken by the authors of this paper from originals in Portuguese.

However, use of A&M in the classroom can cause problems in the accommodation of content, such as attributing the target with characteristics of the vehicle that it does not have or even leading the pupils to understand that the vehicle and the target are the same thing. So for example in hearing that "stars are like little lights in the sky" the pupil could imagine that during the day someone throws a switch and turns the stars off.

The teacher needs to be conscious of Conceptual Metaphors found in science, since Amaral (2006) warns that

> The Conceptual Metaphor doesn't always facilitate comprehension of concepts that are described in terms of others because there may be an unconscious comparison made by the person who encounters this transposition of context (Amaral 2006, p. 25).[5]

So inadequate Conceptual Metaphors found in science or even an inadequate approach to content development in the classroom can result in the pupils who create them forming erroneous ideas. These may not be corrected resulting in the pupils retaining them thus distorting their understanding of the concept being addressed.

An example of this is the Conceptual Metaphor "The Amazon is the lungs of the world". Its use in the classroom could lead the pupil to adopt ideas like:

- The Amazon produces oxygen and the lungs do, too;
- The majority of the oxygen found on the planet comes from the Amazon.

However, we know that:

- The lungs do not produce oxygen. On the contrary, they take up and use oxygen.
- The majority of the oxygen found on the planet comes from the sea, that is, marine algae.

The methodological use of A&M can be a valuable instrument for didactic evaluation. According to Nagem (1997) it encourages

- development of hypotheses;
- resolution of problems;
- evaluation of learning;
- varied and motivating class development;
- conceptual changes since it can use simple language that is familiar to pupils.

However, Nagem suggests that it is important to consider some points that require care in using A&M as a didactic tool:

- There could be differences between the analogy transmitted by the teacher and that received by the pupil, that is, what the pupils understands;
- It is debatable whether the teacher's analogy is accepted by the pupil, since the pupil did not help to develop it;
- The analogy could become more important than the underlying concept if the pupil focuses on the vehicle.

Problems arise in assimilating analogies and metaphors when they are not systematically and methodologically employed. Felipe et al. (2006) suggest that

[5] The translations of Amaral (2006), Felipe et al. (2006), and Duarte (2005) on this page were undertaken by the authors of this paper from Portuguese originals.

> … all expressions are ways of introducing an analogy (Glynn et al. 1998).[6] The criticism leveled at these expressions by Glynn et al. (1998) is that if they are employed non-systematically, the way the analogy should be interpreted may be incorrect. As a result, the distance between the source concept, the target concept and their characteristics become confused in the pupils' minds. (Felipe et al. 2006, p. 2).

In a study of scientific literature from the 1980s and 1990s on the subject, Duarte (2005), mentions errors which teachers often make when using analogies and metaphors in the classroom. The errors mentioned by the author are:

- little use of analogies;
- inadequate use of analogies;
- teachers mixing up analogy and example;
- little opportunities for pupils to develop analogies;
- little evaluation of efficiency of the analogies used in the learning process;
- little relationship between experiences of teachers and the analogical resource;
- frequency of and criteria for the use of analogies appears to be related to the pedagogic viewpoint of the teacher and the teaching strategies developed according to this viewpoint or the personal style of the future teacher.

According to Nunes et al. (2007), there are few studies related to A&M in Brazil. Regarding the use of A&M in class, studies by the research group for *Analogies and Metaphors in Technology, Education and Science (AMTEC)* such as those by Pádua (2002), Marcelos (2006) and by other researchers such as Ferraz and Terrazan (2002) and Monteiro (2005) point out a situation similar to research by Duarte (2005) which highlighted the non-systematic and non-methodological use of these resources in science teaching.

So in order to avoid problems in learning, it must be stressed that, in utilizing analogies and metaphors, the teacher should be conscious of the nuances associated with these techniques and use them in an appropriate methodology. We stress the existence of specific teaching methodologies for the use of analogies and metaphors, among them are those by Cachapuz (1989), Brown and Clement (1989), Spiro et al. (1989), Glynn (1991), Harrison and Treagust (1993), Wong (1993a, b), Treagust et al. (1996), Newton (2000), Galagovsky and Adúriz-Bravo (2001) and Nagem et al. (2001a). In these works, the analysis of differences and similarities between the target and the vehicle used and the importance of prior knowledge are common threads. Marcelos and Nagem (2010, pp. 607–608) refer to the Teaching with Analogies (TWA) method outlined by Glynn (1991) and Methodology of Teaching with Analogies (MECA) of Nagem et al. (2001a), establishing comparisons between them. It is important to note that the term target is used in both methodologies for the domain that is being taught. However, MECA uses the term vehicle for the known domain, while it is called 'analog' in TWA.

The following points summarize the work of Marcelos and Nagem (2010) with a few modifications. To simplify comparisons between the two methodologies, the TWA term 'analog' is replaced by the term vehicle found in MECA.

Often cited in academic works, the TWA methodology involves the following steps:

1. Introduce the target concept
2. Review the vehicle concept
3. Identify relevant features of the target and vehicle
4. Map similarities

[6] Glynn et al. (1998).

5. Indicate where the analogy breaks down
6. Draw conclusions.

The less-cited MECA proposal has five steps:

1. The vehicle is presented
2. The target is presented
3. The similarities and differences between the vehicle and target are analyzed, clearly and objectively explaining those that are relevant for comprehension of the target. There should be more similarities than differences, and the similarities need to be reinforced. The authors suggest that the differences not be given much emphasis in order to avoid straying from the objective of the analogy, that is, showing the similarities between the vehicle and target.
4. Reflection: the pupils and the teacher carry out an analysis of the validity of the analogy and its limitations, checking where the analogy might fail as well as how applicable it is to the proposed content. This procedure should encourage a critical and reflective attitude.
5. Evaluation: the pupil is stimulated to create new analogies containing the same target, thus demonstrating analogical reasoning.

Despite the apparently numerous similarities, the TWA and MECA methodologies are sufficiently different that they can contribute to distinct forms of learning with analogies. Some differences are discussed here.

MECA introduces the vehicle first and then discusses the target, while TWA does the opposite. The MECA procedure can be more inspiring in the teaching–learning process since it seeks to make the analogy available to the learner at any stage, thereby functioning as a motivating element.

In the MECA procedure, pupils are able to explore ideas about the nature of the target, leading them to suggest possible analogical relationships that the educator has not considered and that often extend the content to be taught; these relationships can then be analyzed and later employed when studying other topics.

MECA introduces the target in the second step, whereas TWA introduces the vehicle at that stage.

Introducing the target second, as MECA proposes, awakens the curiosity of the pupils about its nature, encouraging involvement.

The third step of the TWA method involves listing the characteristics of the vehicle and target in order to compare them in the fourth step.

While, MECA proposes that the characteristics of the target and vehicle are listed and compared, checking where they are similar and different. Considering that the use of analogies is a process of construction and reconstruction of knowledge, establishing similarities and differences between the vehicle and target at the same time as the characteristics are listed encourages reflection and allows analogical reasoning to develop.

After comparing the target and the vehicle, the next step of TWA is to identify the limits of the validity of the analogy used.

MECA proposes that the teacher and pupils at this moment list and compare the limitations of the analogy and its validity simultaneously, deciding where it might break down as well as how appropriate it is to the proposed content. This procedure seeks to encourage a critical and reflective attitude in the pupil, helping the pupil to avoid becoming fixed on the vehicle, considering it as if it were the target.

Finally, the TWA model proposes that a concluding synthesis be made of the target in question. On the other hand, MECA proposes that the teacher asks the pupil to develop a new analogy using the same target, thereby developing skills in analogical reasoning.

A substantial difference between MECA and other methodologies is the fact that the examination of similarities and differences between the vehicle and target does not place limits on the analogy. MECA offers the pupil and the teacher a greater degree of freedom for analogical reasoning. In addition, in allowing the pupil to substitute the vehicle with another from his or her own knowledge, it can illustrate the process of accommodation of knowledge.

After learning about the existing methodologies for teaching with analogies, the educator must choose the most appropriate methodology for the learners in question. Thus, the teacher must be aware of a range of methodologies associated with analogies and metaphors in teaching science content.

It is important that, in choosing a methodology, the teacher gives special attention to the prior knowledge of the learners. Contenças and Levy (1999, p. 81) state that the 'degree of intelligibility of the metaphor depends of the degree of familiarity the pupil has with the concepts of the known domain'.[7] Thus before working with the 'Tree of Life' in class, the teacher must ascertain the knowledge and understanding which the pupils bring with them regarding the vehicle tree.

2.3 Training of Teachers to Use Analogies and Metaphors

Oliva (2008) describes what science teachers need to know about using analogies and metaphors. Because of their widespread application in science teaching, teachers need to better understand how to use these techniques.

Oliva suggests that teachers must[8]:

- distinguish analogies from other techniques, since there is some mix up of analogies and models, examples and experiments;
- justify their use of analogies in communication generally and more specifically in science education;
- know historical cases where analogies and analogical reasoning have been used, as they are central in developing scientific knowledge;
- know the mechanisms of learning by analogies;
- recognize the processes involved in analogical thinking;
- evaluate pupil activity and the teacher's supervision of that activity;
- possess an ample and varied repertoire of well-constructed analogies.

He also suggests that teachers should be skilled in:

- selecting good analogies;
- analyzing the limitations of analogies used;
- planning activities for the development and application of analogies;
- adequately monitoring pupils in construction of analogies;
- incorporating the use of different analogies to explain the same target.

[7] The authors' translation of an original text in Portuguese.

[8] The authors' translation of an original text in Spanish.

Adequate training of teachers, especially science teachers, must include the features described by Oliva (2008). In Duarte's (2005) text, there is no report of the existence of teacher training courses that incorporate the use of A&M in science teaching.

There is no evidence to indicate whether there is any proposal to implement the theme in Brazilian teacher training. Certainly in the 14 years during which the A&M research group has been working with teachers, there is significant anecdotal evidence that teachers were not given any training in the methodology or use of A&M in teaching. The frequent use of analogies in science teaching without any underlying methodology supports that evidence.

In Scotland and England, Bóo and Asoko (2000) and Tobin and Lamaster (1995) report the existence of A&M in the national teacher education curriculum. In Brazil, there are no similar initiatives. Regarding Biology teacher education, the *National Curriculum Directive for Biological Science Courses* (Brasil 2001) does not contain specific information about teacher education dealing with analogies and metaphors in the classroom; only very general pedagogical techniques are referred to in such courses.

> The University education procedures should address, beyond specific Biological Science content, content in the areas of Chemistry, Physics and Health in order to satisfy primary and secondary education curricula. They should also emphasize instrumentation for Science teaching at the primary level and for Biology teaching at the secondary level[9] (Brasil 2001, p. 5).

However, despite the lack of A&M support in educational training in Biology, the Ministry of Education does recognize A&M in the 2007 Brazilian Secondary Education Program Guidebook, PNLEM (Brasil 2007). PNLEM is a Brazilian government program for providing Brazilian public schools with all of the curricular content of secondary education (that is, for pupils aged 15 through 18). Every 3 years, authors of textbooks are invited to present their books and submit them for evaluation by specialists in the relevant discipline, using diverse criteria in the evaluation. Among all of the books evaluated, ten from each subject are chosen by the specialists and sent to the schools. Then, teachers examine the texts and choose which will be adopted in their school the next year. Finally, the government sends copies to the school.

The specialists are asked by PNLEM to eliminate any textbooks which do not make sufficient use of analogies and metaphors. They are required to justify their recommendations with specific examples if possible. The texts must first be evaluated according to the following criterion:

> The analogies and metaphors present in the textbook are not properly used and lacking necessary explanation of similarities and differences with the phenomena studied. ( ) Yes (Present arguments below, with examples) ( ) No. Observations: (Brasil 2007, p. 4)[10]

The second classifying criterion in the list deals with adequate use of A&M in each textbook. In this case, the specialist must judge the book using the following scale: *excellent*, *good*, *poor*, *unsatisfactory*. Then he must justify his response and give examples, as follows:

> Appropriate use of analogies which are clearly explicit about the difference between the literal and metaphorical meaning, encouraging correct understanding of concepts, theories, phenomena, etc. Considering the aspects above, the textbook is evaluated as Excellent ( ) Good ( ) Poor ( ) Unsatisfactory ( ) Justify the rating. Give examples. (Brasil 2007, p. 5)

[9] Authors' translation of an original text in Portuguese.

[10] All of the citations of Brasil (2007) in this paper are from the original Portuguese.

According to Giraldi and Souza[11] (2006, p. 11) "the use of analogies in 'biology textbooks is very common". Silva and Trivelato consider that investigations of this type are very important, observing that "Textbooks are often used as the main curricular material in Science teaching, habitually becoming the only vehicles of learning" (Silva and Trivelato 1999, p. 01).

Textbooks could thus direct the work in the classroom and serve as a reference for both teacher and pupil. In this aspect, analogies and metaphors present in texts and exercises as well as illustrations deserve special attention: through their analysis, ideas are developed and assimilated by learners.

As a result of research surrounding the use of analogies and metaphors in teaching and in textbooks, there is an increasing awareness of it among official agencies. If teachers have sufficient support, they can better deal with the use of A&M in textbooks as well as employ the appropriate methodology in the classroom.

2.4 Explaining Evolution by Means of Trees

The use of the tree as a vehicle to explain the target relationships between living beings is not recent. In describing the evolution process that results in the formation of new species in the book *The Origin of Species*, Charles Darwin symbolically utilized the morphological aspects of a tree. According to Spivak (2006), the tree was employed by Darwin to explain evolution:

> Charles Darwin, "the father of the Theory of Evolution", didn't just illustrate the results of evolution using a tree (present organisms and their ancestors) but also the causes of evolution (for example, the concept of natural selection and survival of the fittest)[12] (Spivak 2006, p. 02).

The reference to a tree comes about because of a metaphorical term used by Darwin, 'Tree of Life', and by analogies established with the evolutionary process in the summary in chapter 4 of *Origin of Species*. According to Dreistadt (1968), the strength of Darwin was that he perceived the metaphor more than other scientists had before. In other words, he was not the first to use the image of a tree to explain the relationships between living things.

Regner (1997) displayed various metaphorical conceptions in the 'Tree of Life' though she does not classify them as Conceptual Metaphors and seldom makes a reference to the existence of metaphors in everyday life as did Lakoff and Johnson (1980). Al-Zahrani (2008) adopted the Lakoff and Johnson theory, using it to classify various metaphorical conceptions found in *The Origin of Species* as Conceptual Metaphors. These metaphors included 'nature is a mother', 'nature is a breeder', 'life is war' and 'life is a race'. According to Al-Zahrani they are central to the development of Darwin's theory.

Marcelos and Nagem (2010) show relationships between the 'Tree of Life' and 'Conceptual Metaphors':

> … we cite the conceptual metaphor *Evolution is a Tree*. In this metaphor, there is a conceptual system characterized by: having branches, losing branches, giving rise to other branches and keeping branches, among others. (Marcelos and Nagem 2010, p. 601)

As for the use of illustration, *The Origin of Species* does not have a single edition that clearly represents the morphological characteristics of a tree. According to Ferri et al.

[11] The quotations from Giraldi and Souza (2006) and from Silva and Trivelato (1999) were translated by the authors of this paper from texts in Portuguese.

[12] Authors' translation of an original text in Spanish.

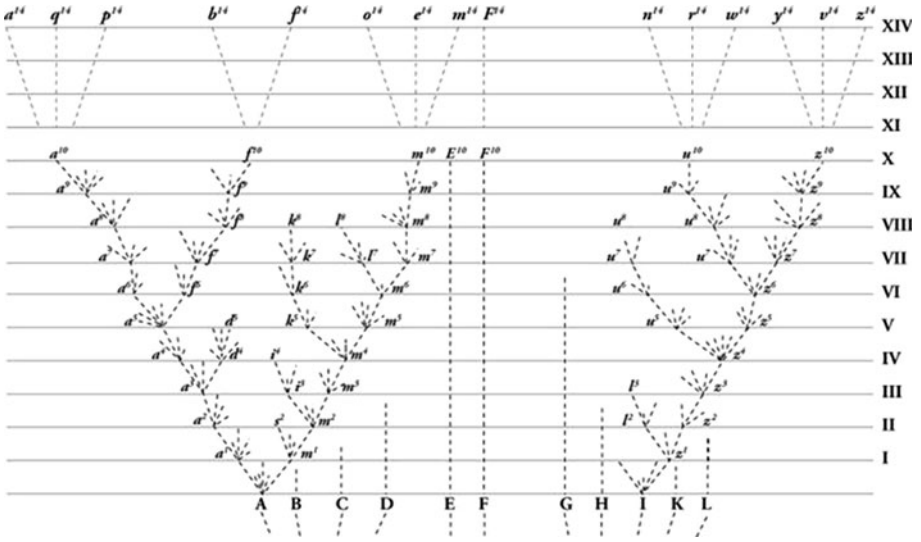

Fig. 1 Diagram contained in chapter 4 of *On the Origin of Species by Means of Natural Selection*, 1859. *Source*: Darwin (1859)

(2003, p. 11),[13] "a tree is an upright ligneous plant, made up of a trunk that branches at the top forming a crown". For Vidal and Vidal (1986, p. 88), the trunk has the following characteristics: "woody, resistant, cylindrical or conical, branched, developing upright above the soil". The only illustration present in the book in question is a diagram that seems plant-like, reproduced (Fig. 1). The illustration does not align with the definition of a tree cited above since it has no trunk nor crown.

In the diagram above, the capital letters indicate close relatives. The intervals between them correspond to the degree of similarity between them. Letters A and I are widespread common species, with the divergent lines parting from them corresponding to their descendants. Horizontal lines from I to X show successive generations that are represented by the lower-case letters followed by a number. The same scheme is repeated giving rise to other species, symbolized by other lower case letters. The dotted vertical lines from XI to XIV indicate continuity of the process in further generations. All points on the diagram are hypothetical—they do not refer to any specific species.

The pioneers in the use of trees as a means of explaining relationships between living beings are said to be the European monarchs and their family trees. In ancient Europe those representations of monarchial relationships were common and, over time, were simplified and became closer to the structure of a plant.

Spivak (2006) states that the first representation of biological relationships between living beings, by means of a tree, occurred in 1801. This representation illustrates the relationships between vegetables without chronological reference to their rise.

However, it was Ernst Haeckel (1866) who first used the illustration of a tree to represent evolutionary relationships (Fig. 2).

Recent works such as O'Hara (1997) and Smith and Cheruvelil (2009) defend the use of a tree in teaching the evolutionary process. While supporting this use, Nagem and

[13] Quotations from Ferri et al. (2003) and from Vidal and Vidal (1986) were translated by the authors of this paper from documents in Portuguese.

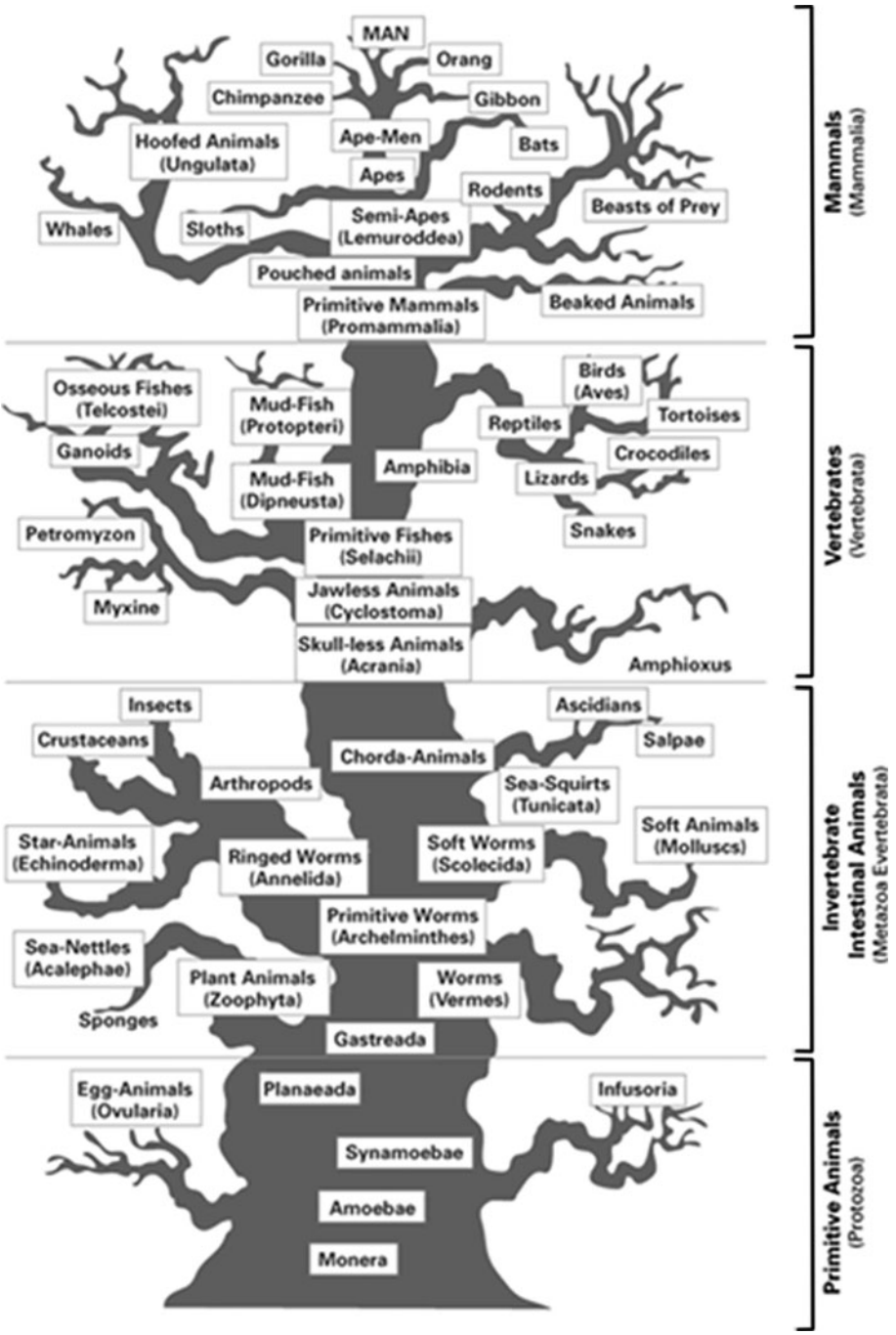

Fig. 2 Haeckel's *Tree of Life*. *Source*: Haeckel (1866)

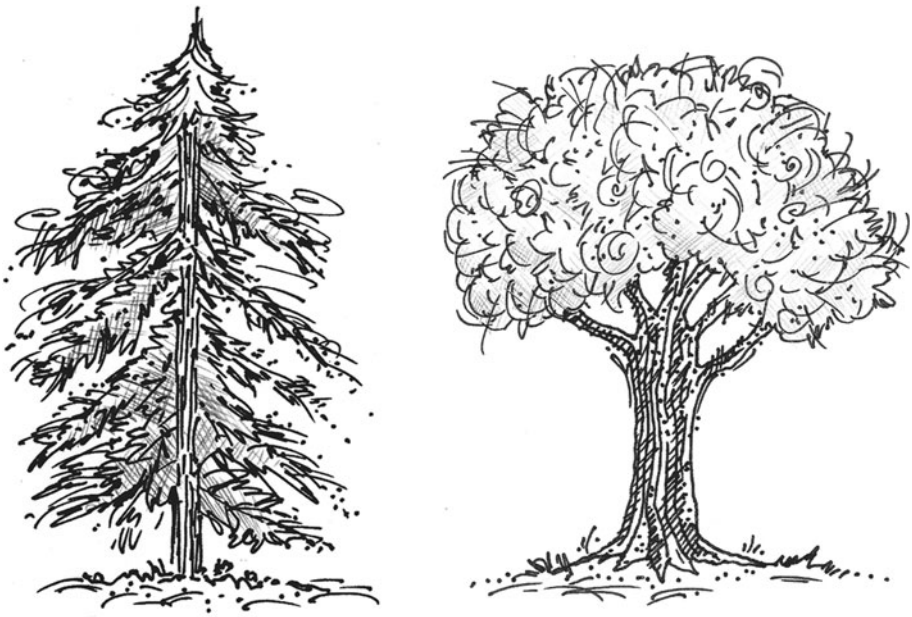

Fig. 3 *Gimnospermae* (**a**) and *Angiospermae* (**b**). *Source*: Figure by Délcio Almeida, Brazilian fine artist and graphic designer, especiallly to this paper

Marcelos (2005) found erroneous representations in Brazilian Biology texts. In the same way Catley and Novick (2008) criticize representation of the 'Tree of Life' found in Biology texts in the USA. These representations, according to those authors, are similar to Haeckel's 'Tree of Life' or are modern representations of it, suggesting the idea of evolution as progress, that is, indicating a progression from more simple organisms located at the bottom of the tree to more evolved organisms at the top. More than an idea, the vision of evolution as progress is a 'Conceptual Metaphor'. It could be that Haeckel's 'Tree of Life' really shows a 'Conceptual Metaphor' and, to that extent, may not present an adequate representation of evolutionary relationships.

The same 'Conceptual Metaphor' could be derived from trees similar to pine trees (Fig. 3a), that is, *Gimnospermae*, since they have an elongated form ending in a top. But many *Angiospermae* trees (Fig. 3b) do not have this structure since the crown is made up of branches that give it a rounded shape without a prominent terminal branch, in contrast to Haeckel's 'Tree of Life' which is also an angiosperm. So some representations are more appropriate than others. An illustration in a text is therefore an analogical representation which needs to be analyzed carefully by the teacher during the teaching process.

In addition, it seems that educators must not limit themselves to the illustrations, but must go beyond them, methodologically exploring Darwin's 'Tree of Life' text, surveying the similarities and differences between 'vehicles' and 'targets', and making the text explicit for their pupils. This approach can produce a better understanding of evolution than a simple analysis of the images of trees and cladograms (ancestral diagrams).

Table 1 presents the 'vehicles' and respective 'targets' actually used by Darwin in his 'Tree of Life' description (see Introduction, Sect. 1 above) based on an analysis by

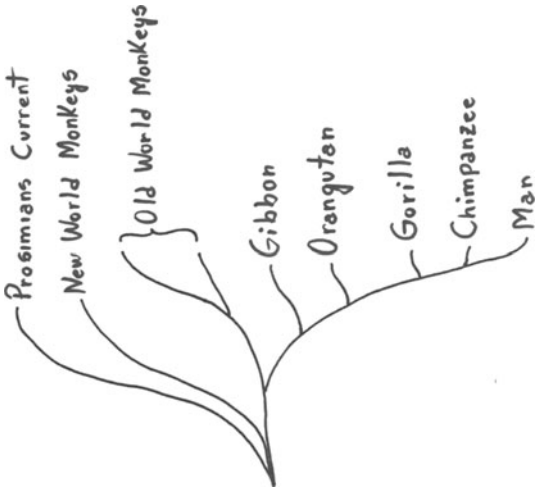

Fig. 4 Reproduction of the "tree" showing the evolutionary relationships between primates, 2005. *Source*: Marcelos (2006)

Marcelos (2006). Employing the classification proposed by Nagem (1997), Marcelos classified the analogies as either 'structural' (between plant structures and groups of living beings) or 'functional' (between processes that occur in plants and in evolution).

Marcelos considers that the analogies present in Darwin's 'Tree of Life' are pertinent as long as they are analyzed methodologically. The analogy, here considered as a cognitive process, leads to establishing possible similarities and differences between two distinct domains. The target is never equal to the vehicle since, if it was, the two would be the same thing and not distinct objects or facts. Thus similarities and differences necessarily exist between domains and they cannot be trivialized by the teacher in the learning process. In systematically employing an analogical methodology, it is the teacher's responsibility to emphasize where the relationships established between the domains are similar and where they differ, encouraging the development of analogical reasoning by the pupil.

Marcelos and Nagem (2010), based on MECA developed by Nagem et al. (2001a), show comparisons between the 'Tree of Life' vehicle and the Evolution target for teaching this topic. They utilized Darwin's 'Tree of Life' concept rather than the diagram present in the *Origin of Species.* Table 2 shows some similarities and differences between the vehicles and the targets of the 'Tree of Life'. These comparisons indicate the sorts of analyses which could be undertaken by a teacher in class. The connections are designed to enable greater understanding of the characteristics of the target. The construction of such charts is an evolving process. Any plausible characteristic could be discussed in the classroom and incorporated into the chart, which grows as new and appropriate comparisons are developed.

Present day formatting of cladograms differs in some respects from those used in Darwin's 'Tree of Life'. For example, in modern cladistics, the species can only be represented at the end points of the branches, never within a branch, and the lines that link

Table 1 Classifying a structural model for tree (vehicle) and evolution (target) from the 'tree of life' text of classical Darwinian theory—2006

Vehicle (tree) Parts of the plant (structural)	Target (evolution) Groups of living beings (structural)
The green and budding twigs	Existing species
The limbs divided into great branches, and these into lesser and lesser branches, were themselves once, when the tree was small, budding twigs; and this connection of the former and present buds by ramifying branches	Classification of all extinct and living species in groups subordinate to groups
Many twigs which flourished when the tree was a mere bush, only two or three, now grown into great branches, yet survive and bear all the other branches	Species which lived during long-past geological periods, very few now have living and modified descendants
Many a limb and branch has decayed and dropped off; and these lost branches of various sizes	Those whole orders, families, and genera which have now no living representatives, and which are known to us only from having been found in a fossil state
A thin straggling branch springing from a fork low down in a tree, and which by some chance has been favoured and is still alive on its summit	An animal like the Ornithorhynchus or Lepidosiren, which in some small degree connects by its affinities two large branches of life, and which has apparently been saved from fatal competition by having inhabited a protected station
Processes that occur in plants (functional)	Processes that occur in Evolution (functional)
Those produced during each former year	The long succession of extinct species
At each period of growth all the growing limbs have tried to branch out on all sides, and to overtop and kill the surrounding limbs and branches	As species and groups of species have tried to overmaster other species in the great battle for life
Buds give rise by growth to fresh buds, and these, if vigorous, branch out and overtop on all sides many a feebler branch	The great Tree of Life, which fills with its dead and broken branches the crust of the earth, and covers the surface with its ever branching and beautiful ramifications

Marcelos (2006) based on the original text by Darwin (1859) available at: http://darwin-online.org.uk/content/frameset?itemID=F373&viewtype=text&pageseq=1

the species represent the degree of relationship between two taxons. Cladograms do not focus primarily on ancestor–descendant connections but rather develop their structure from an analysis of the characteristics which various species have in common. Such differences do not seem to diminish the effectiveness of Darwin's 'Tree of Life' in the classroom. On the contrary, they can enrich the educational process, involving the pupils in active discussions. It is thought that a tree, because it is a vehicle that is more familiar to pupils than a cladogram, could encourage an understanding of the target even though a tree is not actually the basis of modern cladistics. In the classroom setting, such differences between modern cladistics and Darwin's text can be highlighted in the discussions between teachers and pupils as the charts and diagrams are being constructed.

Another suggestion would be to survey the similarities and differences between vehicle 'Tree of Life' and target Evolution and then later to introduce modern cladistics, describing where it is similar and where it is different from Darwin's text.

Table 2 Comparative structural models of similarities and differences between "The green and budding twigs" (*vehicle*) and "Existing species" (*target*) encountered in the 'Tree of Life' by Charles Darwin (1859)—2008

Similarities		Differences	
Vehicle The green and budding twigs	Target Existing species	Vehicle The green and budding twigs	Target Existing species
Twigs and buds give rise to other twigs and buds	Existing species give rise to other species	Twigs and buds give rise to similar twigs and buds	Existing species give rise to different species
The appearance of other twigs and buds is not detrimental to those that spawned them	The appearance of new species is not detrimental to those that spawned them	Twigs and buds are parts of the same individual	Species are formed by groups of distinct individuals
Many twigs and buds co-exist	Various species co-exist	Twigs and buds of the same tree have the same genotype	Different species have different genotypes
New twigs and buds come from other twigs and buds	New species come from other species	The process of forming new twigs and buds is fast	The process of forming new species is slow
		In order to form new twigs and buds, there is no need for mutation	To form a new species, mutation is needed
		Structurally, old twigs and buds sustain new twigs and buds	Old species do not support new species
		The twigs and buds are from the same plant	Species can be from any kingdom

Source: Marcelos and Nagem (2010)

3 Methodology

This study is both qualitative and exploratory. It contributes to science and biology teaching by means of an examination of the use of analogies and metaphors by biology teachers, and by offering support for better training of educators in their use. The goal was to find out whether biology teachers are familiar with Darwin's 'Tree of Life', and if they employ the analogies present in that text, or other analogies between a tree and evolution, systematically and with a specific methodology for teaching with A&M.

According to Alves-Mazzotti and Gewandsznajder (2002, p. 203), the choice of location and participants in qualitative studies does not take place randomly: "the researcher chooses them according to the focus of the study, and taking into account accessibility and on-going availability of subjects".[14]

[14] Authors' translation of an original text in Portuguese.

The investigations were undertaken at a public secondary education institution in the town of Contagem, MG, Brazil. The particular institution was chosen because of the following characteristics:

- it had pupils from ages 15 to 18;
- it had a tradition of public municipal education;
- it encompassed a large part of the town of Contagem, with 10,000 pupils in 19 teaching units during the study period;
- it is known to the public for the quality of its work;
- it had 63 biology teachers on the educational staff.

The investigation procedures included the following:

- observations made in a single classroom
- a questionnaire with open questions for biology teachers who taught the observed classes
- a questionnaire for all biology teachers at the institution
- a focus group involving biology teachers who answered the questionnaire

Although the study did not enquire explicitly about pre-service teacher qualifications or in-service training, some indication of that background in A&M training was sought in the analysis of the data collected. This was done by an analysis of responses to the questionnaires, and during conversations with the teachers in the focus group.

In each phase of the study, the activities were undertaken using the guidelines for ethical research involving people and were characterized by signing terms of partnership, authorizations for releasing data and letters explaining the process to the participants.

3.1 Observation Phase

In Brazil, evolution is part of the curriculum for the senior year of high school, that is, classes with pupils from 17 to 18 years of age.

The observation phase was undertaken within one unit of the school, using classes considered typical of the other school units of the institution. In addition, the following factors were used in deciding on the groups selected:

- It was the biggest unit of the institution, both in physical area and in number of pupils registered;
- There were 1,521 pupils in total;
- There were 11 groups of pupils in the range of 17–18 years old;
- There were 15 biology teachers, the largest number of teachers of this subject for an educational unit;

The group chosen had the following profile:

- Pupils who were willing to be involved in discussions and who had a good level of socialization, enabling greater acceptance of the researcher;
- The most convenient class schedule;
- An experienced biology teacher was available for the study. Therefore, the observation phase took place in classes of the same biology teacher.

In the class observations, the following questions were considered:

1. Did the teacher use terms and illustrations related to a tree when explaining evolution?
2. If so, in what way?
3. Was the expression 'Tree of Life' used in the class discussions?
4. Was there consideration given to the analogies used in Darwin's description of the 'Tree of Life'?
5. What is the influence of the textbooks adopted by the school in question?
6. What are the consequent discussions among the pupils when faced with the analogy?

3.2 Questionnaire Phase

This phase consisted of two parts:

Stage 1 After finishing the observation phase, the teacher was given a questionnaire which included phrases used by the teacher during the class. The phrases contained the term 'branches' and the question asked for an explanation of the term in each case. The particular phrases used are presented in Sect. 4.1.

Stage 2 After stage 1, a questionnaire was sent to each of the 63 biology teachers through the institution's internal mail system. The questionnaire was sent in a sealed envelope to each of the educational units. Respondents were asked to complete the questionnaire and return it in the same envelope.

The survey contained wide-ranging questions related to building a profile of each respondent, and there were also multiple choice questions with some related to the *Origin of Species* text and others related to teaching evolution using the tree analogy, especially Darwin's 'Tree of Life'. The questionnaire had three parts:

Part I: Objective questions about the public profile of the respondent, such as:

- education;
- professional experience.

Part II: A question about reading the book *On the Origin of Species by Means of Natural Selection* with three options for answers and requesting the reason for the choice made. The options were:

A—( ) Read parts B—( ) Read All C—( ) Didn't read

Part III: Multiple choice questions organized in two blocks:

- Block 1—Statements:

– Did the teacher know the expression 'Tree of Life'? The choices were:
  A—( ) No B—( ) Yes
– Did the teacher use comparisons between trees and evolution in teaching the subject? The choices were:
  A—( ) Always B—( ) Often C—( ) Rarely D—( ) Never
– Did the comparison between trees and evolution facilitate understanding? The choices were:
  A—( ) Totally B—( ) Partly C—( ) Very Little D—( ) No

- Block 2—Analogies indentified in the 'Tree of Life' were presented from Table 1 (Sect. 2.4, above), asking about the frequency with which the teacher used them in teaching evolution. The choices followed the Likert scale:

A—( ) Always B—( ) Often C—( ) Rarely D—( ) Never

Part IV: A multiple choice question about the importance of using analogies between a tree and evolution as a teaching tool with four options of choice, again following the Likert scale:

A—( ) Very Important B—( ) Important C—( ) Not Very Important D—( ) Not Important

The choice to participate was given to those who were available for this task subsequent to a meeting between teachers, administrators and other administrative employees in each school unit. Biology teachers did not participate in these meetings. It was the responsibility of a group of assistants to stimulate participation among biology teachers, to collect the questionnaires or instruct participants to return the surveys by the specified deadline. Various options were given for returning the document: through the survey assistants, via inter-office mail, or directly to the researcher or by email or fax.

3.3 Data Collection Focus Group Phase

After the surveys were collected and analyzed, respondents were invited to take part in a focus group. The purpose was to obtain complementary information and clarify some responses in the questionnaire, as well as addressing issues which arose during correlation and analysis. The following questions guided the proceedings:

1. What did you think of the questionnaires: easy, difficult? Why?
2. What did you think of the comparisons between a tree and evolution in the questionnaire?
3. When and how have you used a tree to teach evolution?
4. Which aspects of a tree do you explore in you classes?
5. Why does using a tree totally or partially facilitate learning of the concept? How does it do this?

The replies were incorporated into the graph of the responses of the focus group.

In the focus group, the atmosphere was intentionally pleasant with informal conversation in order to make the teachers comfortable in expressing their opinions. For this reason the participants were seated in a circle and after the introductions were told about the objective of the meeting. The meeting began with a conversation about the daily life of the teacher and then the subject of the research was addressed. The questions that guided the procedure were introduced gradually as part of casual conversation. An effort was made to interfere as little as possible in the participants' discussion in order not to inhibit their comments. The audio of the entire proceeding was recorded subsequent to a freely signed consent agreement by the participants, as explained in Sect. 3 above.

4 Results

4.1 Class Observation

In the 23 classes observed, the most important aspects of the topic were presented, followed by class work and correction. The student text did not make reference to Darwin's

'Tree of Life' nor was there any comparison between a tree and evolution. This lack of reference to an evolutionary tree was thought to be the determining factor in the absence of the teachers' use of comparisons between the tree vehicle and evolution target.

In the last two classes, the topic of Human Evolution was addressed. In each class, the teacher used another book which used a tree by way of an illustration that represented the evolution of primates. From this, aspects of the tree vehicle were emphasized to explain the content, confirming the views of Silva and Trivelato (1999) about the importance of the textbook as a teaching tool. The use of this tree illustration could lead to language that is simpler and more familiar to the pupils, which is one of the advantages of using analogies in class (Nagem 1997).

However, no efforts were made to determine previous knowledge of the pupils about trees, in contrast to the suggestions of Contenças and Levy (1999). In addition, neither the expression 'Tree of Life' nor Darwin's text referring to it were used. The teacher often pointed out the presence of branches during his explanation, which suggests that analogies *are a teaching tool*. However, the information was not explored using a formal methodology, corroborating Duarte's (2005) data about the non-methodological employment of A&M in the classroom. This absence of adequate methodology is contrary to the views of Oliva (2008), who suggests that teachers should specifically plan activities which enable the development and application of analogies, and that they should analyze the limitations of analogies used. During the teacher's presentation, the illustration contained in the book was reproduced on the board (Fig. 4), with the idea of common ancestors and relationships between species being addressed.

The teacher did not analyze the illustration as an analogical representation, establishing comparisons between the tree vehicle and the evolution target. According to Nagem (1997), that could lead to the undesirable result that 'differences may exist between the analogy transmitted by the teacher and the analogy received by the pupil, that is, what the pupil understood'. There was also no attempt by the teacher to check the pupils' previous knowledge of the vehicle in question although this is an essential requirement in teaching using analogies. Such an oversight is contrary to the views of Oliva (2008) who argues that the teacher must recognize the procedural nature of analogical thinking. In addition, the teacher did not explain that the illustration was only part of a large evolutionary tree made up of all organisms live and extinct. The teacher could not be considered to have employed a methodology intended specifically for teaching with analogies, since the issues described above are commonly incorporated in formal teaching methodologies. Such omissions enable 'differences in understanding to occur between what is transmitted and what is received' by the pupil, as pointed out by Nagem (1997).

In the teacher's explanation, the focus was only on the evolution target without considering features of the 'Tree of Life'. This situation can be illustrated by a statement by one of the pupils in a follow-up discussion with the researchers:

> He (the teacher) didn't touch on the "tree" as the center of the explanation. He put the species down and then went on. But if a "tree" was to be understood, he would have had to touch on "tree" and so on, understand? (Pupil 4)

Throughout the lesson, there were no questions or comments by pupils relating to the representation of analogies and metaphors. The pupils remained passive throughout the class, contrary to the suggestion of Oliva (2008) that, when using analogies in class, the teacher should act as a regulator, encouraging pupil input. According to Nagem (1997), one of the disadvantages of using analogies without a methodology is that 'it isn't the pupil

who generates the analogy and so its acceptance by the pupil may be questionable'. This passivity also indicates that, using the approach described, the teacher was unable to make the class 'varied and motivating', one of the advantages of adopting a formal methodology for teaching with analogies (Nagem 1997).

The teacher's phrases where the term 'branch' as a characteristic of plants was used:

Phrase 1 There were primitive prosimians that would have given rise to all present primates. In one group of them, right, where an evolutionary line arose without direct branches, about 70 million years ago, there was almost a direct line between primitive prosimians and current prosimians, which is the case for the Lemur, right?

Phrase 2 New world and old world monkeys were a branch, a separation from the ancestors of man around 25 thousand years ago.

Phrase 3 There was a branch that gave rise to all primates who were called "great apes";

Phrase 4 So from this moment there was a branch here [pointed at the illustration] from chimpanzee to man, that would have occurred more or less 5 million years ago…

Phrase 5 This evolutionary branch that happened giving rise to all of the primates would have taken place about 70 million years ago;

Phrase 6 This Homo Sapiens would have close characteristics to Homo Erectus and underwent the process of evolutionary branching, giving rise to Neanderthal Man and Cro-Magnon.

In clarifications by the teacher in phase 1 of the survey, after the observation process had been concluded, he indicated that, in employing the term 'branches', his intention was 'to give the idea to the pupils that, at the points in time when the tree branched from one group (species), by the process of evolution, new species (arose)'. He thought that, while he had worked on the idea of 'evolutionary factors, natural selection and the process of speciation', he did not explicitly relate them to the characteristics of the 'tree' that was illustrated and analyzed. For the teacher, in all the phrases, the term 'branch' had the same meaning, 'making a connection between the times when organisms differentiated giving rise to new species'. Thus the term 'branch' was used with a meaning different to that indicated by Darwin in his analogy. In the classroom situation, the term took on a functional character while in the 'Tree of Life' it is the vehicle in a structural analogy. This suggests that for the teacher, the term 'branch' in the evolutionary context is used as a Conceptual Metaphor*: branching is a process*.

In a similar context, another Conceptual Metaphor is seen in the justification given by the teacher for using the term 'branch': *bud is time*.[15] According to Amaral (2006) a Conceptual Metaphor can interfere in understanding a concept.

There was never a clear explanation of the term, neither in Darwin's sense nor in that intended by the teacher. As a result, the possibility arises for metaphorical misinterpretations by the pupils, creating different meanings from those conferred by Darwin in relation to the term 'branch', allowing erroneous concepts to be learned.

At the end of the class, the teacher did not use analogies to test learning, a process specifically suggested in *MECA—a Methodology of Teaching with Analogies* (Nagem et al. 2001a) and highlighted by Nagem (1997) as one of the advantages of using analogies in teaching.

4.2 Questionnaire

In phase 2, data collection by means of a questionnaire, of the 63 instruments sent out, 31 (49.2%) were filled out and returned.

Replies to part I of the questionnaire indicated that all of the respondents had degrees and were licensed. Sixteen of the respondents, (51.7%) did not have postgraduate instruction, neither Masters nor Doctorate. The majority of the remainder, 11 respondents (35.4%), were specialists in Biology. Two teachers (6.5%) were studying for their Masters Degrees and one (3.2%) has a Doctorate. One teacher (3.2%) did not answer the question.

Regarding professional experience, a little more than half of the group (51.6%) had at least 5 years in the profession. Only one teacher had more than 25 years of practice.

In part II, the teachers were asked if they had read *On the Origin of Species by Means of Natural Selection,* by Charles Darwin. More than three quarters (77.4%) claimed to have read the book. However, in the majority of the cases, they had not read the whole book. Table 3 shows the results.

The fact that the book had not been read in its entirety by the majority of teachers suggests that very probably the majority of teachers do not know Darwin's 'Tree of Life' text. Because of the importance of the concept in *Origin of Species*, a lack of knowledge about it runs contrary to the views of Oliva (2008) who argues that teachers should *know historical cases of analogies and analogical reasoning, keys in building science.*

The various justifications given by those who had not read the book had a common theme: they admitted that they as individuals were responsible for such lack of knowledge, citing lack of interest or information as the dominant factor.

A significant number of the respondents had read part of the book at university, while only three said that they had read the whole book because it was required in their undergraduate study.

Because of the small number of respondents who said that they had read the whole book, reading *On the Origin of Species by Means of Natural Selection* evidently was not emphasized in their academic training and even less so was it a part of their professional life. Table 3 shows the reasons given for not having read the book.

In part III of the survey, the first block of questions showed that the metaphor 'Tree of Life' was known by 81.7% of the respondents.

For the question which asked if the teachers used comparisons between trees and evolution to teach content related to the evolution of living organisms, only 13% of teachers responded "never", 26% "rarely" and 3% did not answer. The sum of the "always" (16%) and "often" (42%) responses indicates that 58% of teachers employed comparisons between a tree and evolution as a teaching tool. Importantly, the question did not specify whether the teachers used Darwin's 'Tree of Life' but simply a tree.

Respondents were also asked if these comparisons facilitated learning the content of evolution and 29% said that it totally facilitated while 58% said partly, totaling 87%, very little 3%, no 7%. 3% did not answer.

It seems unusual that this resource is recognized as a teaching tool by 87.1% of respondents though it is only used by 58.1% of the respondents, that is, 29% less. This claim suggests that, despite a large number of pupils claiming to recognize the didactic power of making comparisons between a tree and evolution, perhaps teachers are not fully aware of how much this resource could be richly explored, given that it is used less than expected as mentioned above. In the Introduction (Sect. 1, above), it was stated that

[15] The point refers to the teacher justification corresponding to buds of the tree trunk.

Table 3 Reasons given by biology teachers for not having read the book "*On the Origin of Species by Means of Natural Selection*"—2005

"Have you read Charles Darwin's book *On the Origin of Species*?"	Reasons	Number of responses
No	I didn't have time and don't like to read/laziness/I've never had the opportunity	3
	I've never heard of the book	1
	Darwin's thoughts about species were dealt with in university	1
	No justification	1
Yes	This is essential reading for a biologist/knowledge about the theory of evolution	2
	The book was used in the undergraduate program	3
Partial	Lack of time/many books to read at the same time	7
	It was boring, I didn't like it much	2
	I don't have the work and read about things which I directly work with/I only read about the direct applications	3
	I only read the parts related to my undergraduate course/To do undergraduate work/The book was used when studying evolution	3
	It is necessary to understand evolution	1
	It wasn't recommended in undergraduate studies	1
	I read the most important parts. I read it because I was curious	2
Didn't answer	–	1
Total		31

Source: Marcelos (2006)

analogies and metaphors constantly and spontaneously arise in the classroom in an attempt to relate new knowledge to something familiar to the pupil. Maybe the comparisons between a tree and evolution are mentioned superficially but not in detail or systematically, or so as to deal with the nuances of employing an analogy in science teaching as pointed out by Oliva (2008) and as considered in the teaching methodologies specific to the approach.

In the third part of the survey, in the second block of questions, the aspects of the 'Tree of Life' which were used in teaching evolution were examined. Each analogy in the 'Tree of Life' was introduced, with the following options for answers about the frequency of its use: "always", "often", "occasionally" and "never". The responses to each item show that some features of the tree vehicle are explored more frequently than others.

The first analogy described in the 'Tree of Life' text, the comparison between *the green and budding twigs* and the *Existing species,* is the one which is said to be most used by teachers.

As the 'Tree of Life' text becomes more complex, the rate of use of the tree analogy by the teachers decreased. It can be seen that the sum of the responses "occasionally" and "never" reached higher values than the answers "always" and "often" for all of the analogies except the first: 'present branches with existing species'. The analogy used by

Darwin between "a thin straggling branch springing from a fork low down in a tree, and which by some chance has been favoured and is still alive on its summit" and "an animal like the Ornithorhynchus or Lepidosiren, which in some small degree connects by its affinities two large branches of life, and which has apparently been saved from fatal competition by having inhabited a protected station" is the least applied by educators. The table 4 indicates the percentages of responses obtained in questions 1 through 10 referring to the use of comparisons contained in Darwin's analogical description.

The data suggests a possible lack of knowledge and consequent lack of exploration of a majority of the analogies in the 'Tree of Life'. Since it is an important analogy in *Origin of Species*, as well as in science in general, the data shows a low uptake of the views of Oliva (2008) who argues that the teacher should know historical cases of analogs and key analogical reasoning in the construction of scientific knowledge.

Despite the data obtained in part III, part IV shows that 87% of teachers think it is important to establish comparisons between vehicles and targets of the 'Tree of Life' in teaching this material. Figure 5 shows this data:

Even though 87% of teachers thought the didactic use of the 'Tree of Life' was "very important" or "important", the results shown in the table indicate that less than 40% of teachers frequently use the analogy described by Darwin as a didactic resource. This fact can be explained by lack of knowledge of these analogies, which many teachers only became aware of during the questionnaires. This idea is corroborated by a note one of the teachers made on the survey:

> I'd never thought of linking the branches of a tree to the evolutionary process. I thought that the reasoning was clear to pupils.

Reports of some teachers in the focus group, transcribed below, reinforce this idea:

> When I responded I'd already taught evolution. Then I thought, "Jeez, we sometimes work so hard with a lot of stress so the pupil can understand… Suddenly, if I'd been using this analogy, REALLY comparing it with a tree, not just giving the idea of time, that there was a common ancestor, that from it grew a branch… I think I'd have had a lot less stress. (Teacher 5)
> I was even explaining evolution and emphasized more after having read the questionnaires… Maybe if we'd had access to the questionnaire before, we'd have emphasized it more (Teacher 4).

These comments make it clear that those teachers had never had training regarding the use of analogies between the tree and evolution. This was consistent with the observation made by the study group about a widespread absence of training regarding the use of A&M methodologies by teachers.

4.3 Focus Group

Among the respondents to the questionnaire, five participated in the focus group. The group indicated that they did not use analogies between a tree and evolution as a formal methodology, despite their view that analogies are important for understanding content. This absence of a formal methodological use supports the research by Pádua (2002), Ferraz and Terrazzan (2002), Monteiro (2005), and Marcelos (2006) regarding the use of A&M in the classroom.

As noted above, comparisons between a tree and evolution arise in class by the teacher and are accompanied by visual aids, with the branches being the aspect cited most frequently. The following comments were also made:

– The analogies contained in the 'Tree of Life', presented in the questionnaire, were described as pertinent and essential in teaching the content, supporting the view

Table 4 Percentages of answers to questionnaire about use of comparisons from "*The Origin of Species*" by biology teachers—2005

Question	Always	Often	Rarely	Never	No ans.
"In teaching evolution of living organisms, do you make comparisons between *The green and budding twigs* and *The Existing species*?"	23	29	32	10	6
"In teaching Evolution of living organisms, do you use a comparison between *twigs produced during each former year* and *the long succession of extinct species*?"	6	29	32	26	7
"In teaching Evolution of living organisms, do you use a comparison between *at each period of growth all the growing limbs have tried to branch out on all sides, and to overtop and kill the surrounding limbs and branches* and species *and groups of species have tried to overmaster other species in the great battle for life*?"	16	23	32	23	6
"In teaching Evolution of living organisms, do you use a comparison between *the limbs divided into great branches, and these into lesser and lesser branches…* and *the classification of all extinct and living species in groups subordinate to groups*?"	13	23	26	32	6
"In teaching Evolution of living organisms, do you use a comparison between *many twigs which flourished when the tree was a mere bush, only two or three, now grown into great branches, yet survive and bear all the other branches* and *species which lived during long-past geological periods, very few now have living and modified descendants*?"	19	16	26	32	7
"In teaching Evolution of living organisms, do you use a comparison between *a limb and branch has decayed and dropped of; and these lost branches of various sizes* and *those whole orders, families, and genera which have now no living representatives, and which are known to us only from having been found in a fossil state*?"	10	23	26	35	6
"In teaching Evolution of living organisms, do you use a comparison between a *thin straggling branch springing from a fork low down in a tree, and which by some chance has been favored and is still alive on its summit* and *an animal like the Ornithorhynchus or Lepidosiren, which in some small degree connects by its affinities two large branches of life, and which has apparently been saved from fatal competition by having inhabited a protected station*?"	19	10	23	42	6

Source: Marcelos (2006)

expressed by Marcelos (2006), even though few aspects had been exploited by teachers;

– Utilizing analogies with trees was described as essential for teaching evolution since it facilitates learning about evolution by associating the new knowledge—evolution—with something that is part of something already widely known (a tree), assisting in understanding the concept, and supporting the views of Cachapuz (1989).

The teachers' comments indicate a lack of knowledge in specific methods for teaching with analogies, as also suggested by Duarte (2005). Nevertheless, the methodology was not seen as an impediment in the teaching–learning process, as the comment below shows,

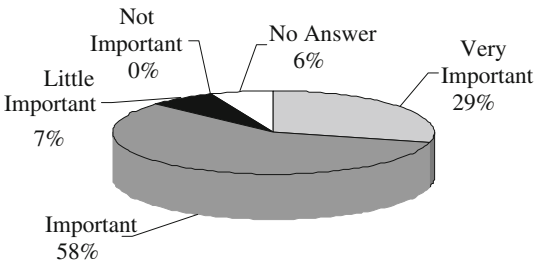

Fig. 5 The didactic importance of the Tree of Life according to biology teachers. *Source*: Marcelos (2006)

suggesting a lack of awareness of the disadvantages of not using an appropriate methodology, as has been described by Nagem (1997).

> I don't think that methodology is the problem. The problem is that the resources that we make available aren't sufficient for us to go deeper into the content. (Teacher 2).
> *Source*: Marcelos (2006)

The lack of commitment to introduce a teaching methodology for A&M is a concern since, if they are not used within an appropriate methodology, analogies and metaphors open possibilities for misunderstandings in assimilating new content, as argued by Felipe et al. (2006), drawing on work by Glynn et al.[16] This lack of commitment results in a lack of teacher knowledge associated with issues surrounding the use of analogies and metaphors in teaching.

Having participated in the survey questionnaire, teachers' awareness of the use of analogies in the 'Tree of Life' as part of the teaching–learning process arose as a new piece of knowledge. Realizing the new possibilities for teaching, they seemed surprised and enthusiastic, suggesting some advantages that could come from using the analogy. They indicated that, having completed the survey, it would be important to incorporate the analogies presented in their own teaching. This supports the observation that teachers did not have prior access to information regarding the methodological strategies possible in the use of analogies and metaphors.

Table 5 shows the comments the teachers made about the deliberations of the focus group.

It was apparent that the responses obtained from the focus group discussions reinforced the analysis of the data obtained in the questionnaire, confirming that:

- The participants do not know the 'Tree of Life' text.
- Only some aspects of a tree (branches) are explored in class, unlike in Darwin's text where other aspects of trees are used as well.
- The participants seemed unaware of methodologies related to teaching with analogies.

[16] Glynn et al. (1998).

Table 5 Comments made by biology teachers regarding the questions in the focus group and considerations of the researchers—2005

Questions	Transcribed comments	Observations
1. What did you think of the questionnaires: where they easy or difficult? Why? How did you feel when you responded to them? Objective of the question: To ascertain whether the respondents had trouble responding to the questionnaires, which could have influenced the results	I think that it was very clear, I didn't have any trouble at all. It was very specific about evolution… When I responded I'd already taught evolution. Then I thought, "Jeez, we sometimes work so hard with a lot of stress so the pupil can understand… Suddenly, if I'd been using this analogy, REALLY comparing it with a tree, not just giving the idea of time, that there was a common ancestor, that from it grew a branch… I think I'd have had a lot less stress. It's just that a lot of the time we don't use this kind of thing I was even explaining evolution and emphasized more after having read the questionnaires… Maybe if we'd had access to the questionnaire before, we'd have emphasized it more I regret not having used the tree during…	In the evaluations of the teachers, the questionnaires were clear both in the directions and in the questions. However, they were identified as questionnaires about evolution when in fact they were not researching the level of knowledge of teachers about evolution but the methodology used by the person in teaching it The use of analogies in the 'Tree of Life' in the teaching–learning process arose as new knowledge for the teachers at the moment they took the questionnaire. Realizing the possibilities for teaching, they showed surprise and enthusiasm, suggesting some advantages that could come from this use and they showed a change in their thinking and future action after experiencing the questions in the survey
2. What did you think about the comparisons between a tree and evolution pointed out in the questionnaire? Objective of the question: To find replies that could point to a possible lack of knowledge about the Tree of Life text, since it appeared in the answers to the questionnaire	… our logic of thinking about biology, when we read that, in terms of biology, with the concepts that we already have, that was very clear, but… for us to pass it on to pupils, I do that only sometimes, I don't go to this level with the boys. I also said, you know, it's been a few years since I've taught evolution. I entered in the school administration in 2000 and I've been in pathology since 1998. So it's been a few years since I've been in the senior year. In the time that I taught evolution to the boys, these details were clear to us, but I rarely used them in the classroom	According to the teacher quoted, the analogies exposed on the questionnaire seemed to be clear and pertinent about biological knowledge about evolution. However, it was rarely used in the classroom. This statement was not contradicted by any of the other participants Despite the respondent saying that she knew of the analogies when she was teaching, other comments suggest that the analogies in question only became known to the teacher when she undertook the survey. The teacher reported that she had not used the analogy in class and that she had not taught evolution in many years. It seemed that that the detailed exploration of the 'Tree of Life' was only recently acquired, to justify her educational practices

Table 5 continued

Questions	Transcribed comments	Observations
3. When and how do you utilize the 'Tree of Life' in teaching Evolution? Objective of the question: to determine how the teachers related a tree to evolution in the classroom since on the questionnaire a large majority of the teachers responded that this teaching tool has a lot of potential but that it was not used frequently. This leads to the belief that analogies between a tree and evolution are not being employed with an adequate methodology	I make a very traditional drawing on the board. Very simple, showing the basics of evolution. I address common ancestors, here arose this, there arose that, and why? For this reason and that and that. This question of analogy, of homology, vestigial organs … what leads to these modifications When I was teaching evolution to the boys, these details were very clear to use, but in the class I rarely used them …I don't go into this much detail with the boys… I think that the methodology isn't the problem, the problem is the resources that we have access to aren't enough for us to go into detail about this subject I actually brought in transparencies dealing with branches. In reality, I compared the process of development of a tree with the developmental process of evolution, but until then I hadn't. What I used to do was to show time… I used them more to show the time at which the branches occurred that gave rise to the species, but as a tree, with comparisons, analogies… In my case, I don't use "tree" just to explain human evolution. Even getting the cases of analogy * and homology ** to explain this, but in general, normally without dealing with the question of human evolution. For example, in the case of mammals: why are we related to rats, for example? We belong to the same class… I get this and go to birds: Why? Then I generalize, not just the question of human evolution	The teachers show that they do not explore the analogy fully, dealing only with some aspects in class. The approach is generally accompanied by representative illustrations, analyzing the branches to indicate factors such as ancestry and evolutionary parents. The factor "time is necessary for evolution" is also dealt with in the explications of the teachers The methodology used was not seen as an impediment in the teaching–learning process. However, there was a consensus about the lack of resources limiting opportunities to deal with the content in depth and in a more detailed exploration of the 'Tree of Life' Despite the methodology not being thought an impediment to the teaching–learning process, the teachers showed that they do not know a methodology specifically for teaching with analogies. This fact lead to the possibility that the teachers in question did not understand the need to employ a systematical methodology of analogies in teaching, much less being aware of the disadvantages of not using analogies as pointed out by Nagem (1997) * The term 'analogy' was used in the transcript comments in the biological sense: 'similarity of structure that depends on similarity of function such as the wings of insects and those of birds. (Darwin 1859) ** Homology indicated organs of the same origin with different functions. E.g. wings of birds and arms of man

Table 5 continued

Questions	Transcribed comments	Observations
4. Why does the use of a tree help the learning of the subject? How does it help? Objective of the question: To identify whether the teachers understood the importance of the methodology for teaching with analogies	I don't think there's another way for us to explain evolution as well as the case of the tree. There isn't anything else that makes the idea of evolution clear Because of the number of branches that we associate with the species. There wouldn't be a way to explain the evolutionary process without using something to represent it. I can't think of another one… making this analogy with something other than a tree Maybe because of the fact that the tree is something from the pupil's life. He already knows about the development of a tree, the growth process, he's already seen the branches of a tree. He has an image of a tree, which is certainly easier to understand than the process of evolution. You use something that is real for him, he's going to absorb more of the idea of the evolution process	The 'Tree of Life' was considered an essential factor for teaching evolution. According to the teachers, it facilitates learning about evolution by associating the new knowledge, evolution, with something familiar to the pupil, a tree, encouraging understanding of the content. In this respect, the analogy makes a bridge between the non-scientific knowledge (easier) and scientific knowledge (harder) taught in school. Only the branches were remembered as aspects to be explored The teachers in the group could not think of any other analogy that could be used as easily The idea of construction of knowledge was not taken into consideration since evolution was seen as something to be taught by the teacher and absorbed by the pupil, in contrast to the idea that teaching by use of analogies is an aid to developing new knowledge The teachers showed that they believed, without specific confirmation, that the development of a plant structure was part of their pupils' previous knowledge
5. Which aspects of the tree do you explore in your classes? Objective of the question: clarify which characteristics of a tree the teachers used in class to teach evolution	…when I was in college I didn't study evolution from the point of view of the 'Tree of Life' and in the first few years that I taught evolution, I also didn't use the tree of life, only later. It had the traditional branches, but dealing in details… …exactly regarding this possibility of a single, general thing, having developed characteristics due to different factors, and so on, and taking care to say to them that it wasn't something that happened from 1 year to the next, there are generations… … understanding of the 'Tree of Life' is easier in the senior year; we often try not to go too deeply into it due to the problems of the pupils and religious questions… …I even brought in transparencies dealing with the branches…	It became obvious in the first phase that the 'Tree of Life' analogy was not part of the training of the teachers in question The teachers think that they do not deal in much detail with the analogy. The parts of a tree mentioned as being commonly explored were the branches Problems associated with religious questions arose as factors that interfere with a fuller exploration of the analogy in class. Again, the teachers did not mention lack of appropriate methodology for teaching with analogies

Source: Marcelos (2006). Based on Nagem, Guimarães and Barbosa *apud* Pádua (2002)

Nagem et al. (2001b)

- A method of teaching that examines relationships between a tree and evolution was not considered important.

The teachers never referred to analogies as common characteristics of everyday language or scientific language, thereby justifying their use in teaching on that basis, much less referring to them as central to acquiring scientific knowledge. Lack of concern about the pupil's prior knowledge points to a lack of knowledge of the mechanisms of learning with analogies since previous knowledge has a fundamental role in this approach to learning. All of these aspects were described by Oliva (2008) as being knowledge that a teacher should have. It is also noteworthy that discussion in the focus group indicated that teacher training did not include the 'Tree of Life', confirming the analysis of part II of the questionnaire.

5 Final Considerations

The results point to lack of knowledge of the analogies present in Darwin's 'Tree of Life'. That is, teachers did not use it in teaching, despite the use of analogies between a tree and evolution to explain content. They also did not employ appropriate methodologies for teaching with analogies, confirming studies by Pádua (2002), Marcelos (2006), Ferraz and Terrazzan (2002), and Monteiro (2005), among others. Based on the data collected, this appears due to lack of knowledge of those methods.

The general lack of knowledge of the 'Tree of Life' on the part of the teachers runs contrary to the views of Oliva (2008), who considers that teachers should know historical cases of analogies and key analogical reasoning in acquiring scientific knowledge. Therefore these aspects have to be considered in training biology teachers.

This research has observed current practice and has analyzed the results of surveys in order to ascertain the current situation regarding the training of teachers in the use of A&M. The data confirms that the theme was probably not satisfactorily addressed during the training of the participants in the research, giving rise to the possibility of incorrect use of analogies.

A significant proportion of the participants, around 50%, comprised teachers with less than 5 years of experience, which suggests that the conclusions apply to current university training. In addition, 49.3% of the participants had experienced higher education (Masters or Doctorate), suggesting that these graduate programs also did not include appropriate training for these professionals in the educational use of analogies and metaphors.

In addition, the majority of the documents from government agencies cited in the references give no consideration to the theme, despite its importance. This is significant, given that the reference to analogies in other official documents and academic research could have implications for teacher training institutions in relation to the issue.

It may be useful to make the present research more widely known, as well as to adopt measures that can contribute to possible improvements in the situation, such as:

– greater emphasis on the methodological use of analogies and metaphors in documents seeking to advise on the development of courses for teachers in biology and the sciences;
– better dissemination of the A&M theme as a teaching–learning resource;
– insertion of the methodological use of A&M into the content in science graduation courses;
– better information about the A&M theme in acquiring scientific knowledge;

– offering in-service teacher courses that deal with this theme.

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