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CELL BIOLOGY ANALOGIES IN BRAZILIAN BIOLOGY TEXTBOOKS: A TEACHER GUIDE BASED ON FAR MODEL

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From a well-established model for the use of analogies in science teaching (Focus, Action, Reflection – FAR Guide) this research aimed to develop a teacher support resource (teacher guide) based on the four most frequent cell analogies in Brazilian biology textbooks which were: DNA as a spiral staircase, complex substrate enzyme as a key and lock, ATP as currency and mitochondria as a power plant. This teacher guide was evaluated by pre-service biology teachers from a Brazilian public university. Perceptions and recommendations were collected by questionnaires, participant speeches' recording and a field notebook. Students' responses were tabulated and analyzed, and these results were evaluated for a current version of the teacher guide. The comprehension of the content was perceptible by the majority of participants, however some of them showed doubts about analogies' limits. FAR Guide was considered a good way to plan use of analogies to a cell biology class and a viable didactic resource to be used in the Brazilian educational context.

Keywords: Classroom Discourse, Higher Education, Biology Education

INTRODUCTION

Analogies are used in different ways, contributing to science learning and teaching, teacher training, and even as research tools (Aubusson, Harrison, & Ritche, 2006). Analogies and metaphors are ways of comparing structures or processes from two different domains, from their similarities, with the intention of expressing something unknown or unfamiliar through something known or familiar (Duit, 1991; Aubusson et al., 2006). The familiar domain is called an analogy and the unfamiliar domain is called a target and, through analogical reasoning, the similarity relationships between these two domains are traced, giving rise to an analogical model (Duit, 1991).

Analogies can benefit the learning of new concepts allowing the student to build relationships between their previous knowledge (analogies) and scientific knowledge (targets) (Glynn, 1991). They also play an important role in the interpretation of scientific complex models by providing mental models from familiar analogies that, although limited, clarify natural phenomena until to learn more complex models (Glynn & Takahashi, 1998). The use of analogies allows an easier and more concrete perception of abstract concepts and structures that are not very tangible to students (Duit, 1991; Treagust, Harrison, & Venville, 1998), as is the case of content related to cell biology.

With regard to cell content, simple analogies are recurrent in Brazilian biology textbooks (Araujo & Guimarães, 2017) and teaching material to assist a systematic presentation of analogies is practically absent in these textbooks. In this way, we see an opportunity to produce support material for biology teacher. To this end, despite the popularity of Teaching With Analogies - TWA (Glynn, 1991) in Brazil, our research team chose Focus-Action-Reflection (FAR) Guide for Teaching with Analogies and Models (Treagust et al., 1998; Aubusson et al.,

2006; Harrison and Treagust, 2006; Harrison and Coll, 2008) for being a pedagogical process that includes not only in-class actions, but also "two important aspects of effective teaching, namely, lesson planning and post-class reflection. A model was sought that would encourage teachers to think about and their presentation before, during, and following lessons in which analogies were used." (Treagust et al., 1998, p. 88).

In this article we report results of a qualitative research on perceptions of Brazilian pre-service biology teachers from a public university about a teacher guide developed according to Focus-Action-Reflection (FAR) Guide for Teaching with Analogies and Models (Treagust et al., 1998). This teacher guide was designed for the most frequent cell analogies in Brazilian biology textbooks. The research took place in a broader context (Oliveira, 2019) also involving biology textbooks analysis, selection and mapping of cell analogies, as well as the collect and analysis of students' prior knowledge about analogies. These results were not included in this article.

METHODS

From the well-established Focus-Action-Reflection (FAR) Guide for Teaching with Analogies and Models (Treagust et al., 1998), a teacher guide was developed for the four most frequent cell biology analogies in Brazilian biology textbooks according to Araujo & Guimarães (2017) and Oliveira (2019). The teacher guide was based on Duit (1991), Treagust et al. (1998), Aubusson et al. (2006), Harrison and Treagust (2006), Harrison and Coll (2008). Our major goal was to develop a teacher guide which could assist Brazilian in-service biology teachers when using biology textbooks in public high schools in their classes about cells.

In concern to teacher guide design, it was formatted in two parts. The first part was concerned to explain, in a general way, the role of analogies in science teaching and how they work in this context. For these purposes, a definition of the theme and an example of a cell analogy was presented: the comparison between the structure of a eukaryotic cell with a city, in a similar way to Venville (2008). Also included in the first part of this teacher guide are the positive and negative points from the use of analogy in science teaching, a historical example of the use of an analogy by a scientist, and a brief explanation of the FAR Guide phases. The second part of the teacher guide had as objective, based on the FAR Guide, to help biology teacher to use the four most frequent cell analogies in Brazilian biology textbooks which are regularly distributed by Brazilian government to public schools through the National Textbook Program. These most frequent analogies were: adenosine triphosphate (ATP) as currency, DNA structure as a spiral staircase, mitochondria as a power plant and the specificity between enzymes and substrates compared to a key and lock.

The structure of the FAR Guide was maintained with the "three stages for the systematic presentation of analogies and resembles the planning phases of expert teaching and the action research model" (Harrison & Treagust, 2006, p. 20). For each analogy, a text was prepared for the Focus and Reflection phase according to the contents of the target and analog domains adopted. In Focus phase, Concept, Students and Experience parts were inferences related to our team-teaching experience. The Action stage was presented through similarities and differences between each specific domain resulting in mappings. In addition to the steps of the FAR Guide, some parts of textbooks with the respective analogy were transcribed. Similar to

what was done in FAR Guide publications (Treagust et al., 1998; Harrison & Coll, 2008), images of each target and analogy were also included in order to illustrate the two different domains.

The teacher guide was evaluated by 54 Brazilian pre-service biology teachers from the University of Brasília (Brasília, Federal District, Brazil). For its analysis, interventions were made during the 2018 second academic semester in different courses in which these students were enrolled. After oral presentations about general aspects of the use of analogies in teaching biology, carried out by our team, students organized themselves into small groups and received the teacher guide for analysis. Each small group has received a specific analogy to consider.

The results of this research are concerned about the second part of the teacher guide which was based on FAR Guide. Students' perceptions and recommendations were collected by questionnaires, participant speeches' recording and a field notebook in a qualitative research approach (Bogdan & Biklen, 1994). Each student answered, according to a specific analogy, five questions regarding the clarity and functionality of each phase of the FAR Guide being possible to make comments and suggestions. Data were tabulated and analyzed in Gibbs' perspective (2009), and results were considered for the current version of teacher guide.

RESULTS AND DISCUSSION

Overall, the teacher guide was evaluated positively by the 54 participants. The FAR Guide developed for the "ATP as currency" analogy was also positively evaluated in all aspects by 17 students. Despite this, some students commented that this analogy should be used with caution to avoid alternative conceptions of the target. One of the students pointed out that the domains are very different, maybe creating some difficulties in the learning process of the target. In face of this observation, it was clear that teacher guide did not allow the understanding of the analogy, which is even presented in Alberts et al. (2017), a reference for pre-service biology teachers during their cell biology courses. Probably, the participant's perception was due to the image chosen to illustrate this analog - a stack of coins - and may imply that the analogy - ATP as currency - would be structural, rather than functional. It is noteworthy that the inappropriate image selection also did not help the student to understand the analogy that is presented in textbooks as follows: "ATP is like energy currency" without any complementary explanation. In current version of teacher guide, a new image was chosen which illustrate a shopping transaction, which is the essence of the analogy in question.

In the other hand, another research participant argued that this analogy is only functional maybe being not efficient to the scientific concept's understanding. As pointed out by Duit (1991), all analogies, by definition, are limited. Venville (2008) stressed about some consideration to be taken in the first two steps, Focus and Action, of the FAR Guide to be sure to explain about analogy and target's attributes. Therefore, recognizing the limits of an analogy is a fundamental factor to stimulate the use of analogical reasoning properly. Because this discussion appeared in other occasions during this research, an additional information related to analogical relationship, as pointed by Curtis and Reigeluth (1984), was included in the current version of teacher guide.

The part of the teacher guide related to the "DNA/spiral staircase", in general, was well evaluated by 15 students. However, some students did not agree with certain parts of the teacher guide, reporting their dissatisfactions with the fact this analogy only serves to explain the structure and does not allow the explanation of the function of the DNA molecule. As in the ATP analogy as currency, these pre-service teachers had difficulties in recognizing the limits of the DNA/spiral staircase analogy that is, in fact, exclusively structural according to Curtis and Reigeluth (1984). A student stressed that she understood the analogical model but recommended the inclusion, in the teacher guide, a greater emphasis on the fact that this analogy is exclusively structural. Another student clearly questioned whether the analog (spiral staircase) is part of her daily life and proposed a school activity to explore the analogy more efficiently. It is emphasized that, in every analogical model, the analog needs to be recognized by the receptor, therefore, the participant's point of view is relevant in the school context (Venville, 2008). As the analogy was assessed using and instructional material prepared by our team and not by a classroom dynamics, as the FAR-Action step assumes to be (Treagust et al., 1998), research participants' familiarity with the analog was not checked and the above student soon realized the need for check receptor's familiarity when using any analogy in the classroom.

During the analysis of the teacher guide's FAR-Reflection phase, one of the students asked: "Would it be interesting to bring another analogy for students to explain the function of DNA, such as an analogy between DNA and the alphabet?", realizing that this analogy also needed for further explanation. The alphabet analogy was included in the teacher guide as inference elaborated by our team when developing the activities of the FAR Post-Lesson Reflection phase, specifically regarding to Improvements. This part was planned to encourage teacher to reflect on the following questions: "What changes are needed for the following lesson? "and "What changes are needed next time I use this analogy?" (Harrison & Treagust, 2006, p. 21). It was noticeable that the insertion of a new analogy in no way helped the FAR-Reflection phase and do not answer these questions. In the current version of teacher guide the alphabet analogy was removed from Improvements.

The students also emphasized that the image adopted to exemplify the spiral staircase could cause confusion for not illustrating a staircase with two handrails, which would be more suitable for comparison with the molecular structure of DNA model. With this perception and that one related to ATP analogy, a more careful image selection had to be done by our research team, also taking in account that in the Brazilian biology textbooks, with regard to the cell content, there are few pictorial-verbal analogies as emphasized by Araujo and Guimarães (2017).

In the teacher guide, the concept of mitochondria was explained in an analogous way by comparing organelle functions to that of a power plant. From the total of 13 student who analyzed this analogy, one of them suggested that in the FAR-Focus of teacher guide, the explanation of the analog should be close to that of the target concept and not interspersed with the projections of possible students' conceptions in relation to the target concept. Such change, in the participant's point of view, could facilitate the reader's understanding about the analogy. However, the FAR Guide is systematically presented with information from Pre-Lesson Focus

in the following order: Concepts, Students and Analog (or Experience) (Treagust et al.1998; Harrison & Treagust, 2006; Venville, 2008). According to cited authors, first teacher reflects on the concept: "Is the concept difficult, single-family or abstract?" (Harrison & Treagust, 2006, p. 21). Then, the concept is analyzed from the students' perspective: "What ideas do the students already have about the concept?" (Harrison & Treagust, 2006, p. 21). Finally, teacher thinks about analogies "What familiar experiences do students have that I can use?" (Harrison & Treagust, 2006, p. 21). The teacher guide was modified following the student's recommendation. But, in future applications of the FAR Guide, we will return to the original sequence verifying, using data from further research, whether such a change is, in fact, really necessary over the logical sequence established in the FAR Guide.

Several students questioned the feasibility of using the mitochondria / power plant analogy considering that it is an analog difficult to understand: the operation of a power plant that produces energy. Such perception is related to a fundamental aspect in the use of analogy in the classroom: analogies facilitate learning when comparing something unknown with something known (Aubusson et al., 2006). According to Araujo and Guimarães (2017) and Oliveira (2019), the analogy in question is presented, in general, in biology textbooks as simple analogy ("mitochondria is a power plant"), usually without complementary explanations and leaving the responsibility for the textbook reader to understand it. In addition, the analogy refers to a specific aspect of mitochondria functioning explored in detail by Alberts et al. (2017), a reference used by Brazilian biology textbooks' authors, and is related to the ATP synthase. In Brazilian biology textbooks, such an analogy is rarely put as follows: "At certain points in the membrane, however, protons can return to the mitochondrial matrix, and in doing so, similarly to what happens in a generator of hydroelectric plant, but in much smaller proportions, they literally spin a molecular rotor. This process, which generates ATP and is called chemiosmosis" (Bizzo, 2016, p. 143). As the main objective of the teacher guide is to assist the teacher who is faced with such an analogy in Brazilian biology textbooks, it will be up to the professional to decide whether or not to explore it in the classroom, ascertaining the student familiarity with the analog. However, it is considered that the most salutary in this research was the perception of participants of the need to establish student familiarity with the analog, as highlighted by Treagust et al. (1998, p. 85): "When using an analogy in science teaching, teachers should select an appropriate student world analog to assist in explaining the science concept."

A student wrote the following: "In the textbook section, it was not clear to me whether it is considered a good or bad use of the analogy". This perception came from the Bizzo excerpt (2016, p. 143) shared above and which stands out, in relation to other biology textbooks, for being an enriched analogy according to Curtis & Reigetluth (1984). Therefore, we must still continue to test if insertion of excerpts from textbooks helps or not the teacher guide user, even if in current version the textbooks' excerpts have been maintained.

The key and lock analogy had the least number of analysis (9), with participants evaluating it positively and being readily recognized as a familiar analogy. The main point highlighted by the participants was the presence of five marked differences between the domains, a higher number than that presented in the mapping of the other analogies. But it is also important to

highlight that even in the face of the obsolescence of this analogy, this aspect was not accentuated by the students who analyzed it. Nelson and Cox (2014) reported that Emil Fischer in 1984, from his findings, postulated that the structures of enzymes would be complementary to their substrates, such as a key and lock. Subsequently, with advances and discoveries in the area, it is now understood that this analogy does not explain perfectly this molecular interaction. However, this analogy still remains in the Brazilian biology textbooks. This perpetuation is due to the fact that the National Textbook Program took into account, in the biology area, the understanding and recognition of the history of science as something beneficial for biology teaching, allowing the presence of this analogy in the biology textbooks with the purpose to stimulate discussions about how scientific knowledge is constructed (Ministério da Educação, 2017). However, none systematic presentation of this analogy is found in biology textbooks, leaving it up to the biology in-service teacher how to use and explore this analogy, not exactly in the perspective intended by the National Textbook Program.

In general, the second part of teacher guide that incorporated the FAR Guide for certain analogies of cell biology was positively evaluated by the participants. Even with the sharing of some criticisms and reservations, 52 students stated that they would use the teacher guide, making recommendations regarding its format and content. Only two students answered that they would not use the teacher guide, claiming that they did not like the analogy they received to carry out the analysis or because they did not feel comfortable using analogies as teaching resources. One of the questions in this research addressed whether the teacher guide would assist in conducting a cell biology class with analogies, and all responses were positive without any reservations. A total of 35 participants wrote that they would explain the contents about the cell with the teacher guide. Of this total, 24 participants would adopt the analogies to start explaining cellular concepts, as one of the students explained: “Just in the situation of explaining about this subject in biology, because I think it is much clearer and easier to learn if you compare something you have already know with something you would like to learn”. The other 11 participants, on the other hand, would also adopt analogies to explain scientific concepts, but as a second option and after a previous explanation of the target concept, a situation exemplified in the response of another student: “I would use it to consolidate the concept of DNA structure after an expository class on each of the elements”. It is noted in these considerations that the participants of this research would choose to use the analogy in the perspective of Glynn (1991) and Glynn and Takahashi (1998). And, mainly, these Brazilian pre-service biology teachers had the opportunity to analyze an instructional material based on the FAR Guide for Teaching and Learning With Analogies (Treagust et al., 1998; Harrison & Treagust, 2006; Harrison & Coll, 2008), a valuable systematic presentation of analogies still not well-known in Brazil.

CONCLUSIONS

To develop, by FAR Guide, and to test a teacher guide to help the use of cell analogies presented in the Brazilian biology textbooks allowed us to verify that Brazilian pre-service

biology teachers are interested in an instructional resource which help to plan the use of analogies.

Most of the analogies related to the cell biology content were presented in the Brazilian biology textbooks without additional explanations (for example, their limits) when compared to the scientific concepts and the participants of this research demonstrated difficulties in realizing that any analogy, by its nature, has such limitations.

Brazilian pre-service biology teachers realized the need to be cautious in the use of analogies in the classroom to avoid alternative conceptions of scientific concepts by students and also the need to establish student familiarity with the analog.

The pre-service teachers' perceptions enabled us to verify that when choosing images to illustrate the analog and inserting it in an instructional material, a careful selection must be made, taking also into account that in the Brazilian biology textbooks, regarding the content of the cell, few analogies are pictorial-verbal.

FAR Guide can become an excellent instructional material complementary to biology textbooks distributed in the Brazilian territory, taking into account that, in the case of cell biology, scientific content is abstract, simple analogies are the most recurrent in these textbooks, with the absence of supplementary instructional material to assist teacher to present analogies in a systematic way.

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