INVESTIGATING THE RELATION BETWEEN DECLARATIVE AND PROCEDURAL PRE-SERVICE CHEMISTRY TEACHERS' KNOWLEDGE ABOUT ANALOGIES

Nilmara Braga Mozzer
Thais Mara Anastácio Oliveira
Rosária Justi

Abstract

In this paper, we investigated the ideas that pre-service chemistry teachers stated about analogies (declarative knowledge) and its relation to the process of elaborating their own analogies (procedural knowledge) striving to facilitate the understanding of the topic chemical reactions for elementary and high school students. Our sample group was made up of 14 pre-service chemistry teachers studying in different semesters of the course. The data was obtained through a questionnaire and validated through interviews with the respondents. This data supports our discussions about interrelationships between what the pre-service chemistry teachers stated they knew about analogies and the way they used their procedural knowledge to elaborate analogies. The analysis of the data supports the conclusion that focusing teachers' training course exclusively on declarative knowledge about analogies does not seem sufficient to support them in elaborating good analogies. From this, we discuss implications for educating future teachers with more authentic conceptions about analogies.

Introduction

An analogy is a comparison in which relations between a familiar domain - the analogue - and an unknown domain or one that is not very familiar - the target (Gentner, 1989) are established. Therefore, they have been recognised as potential useful tools in teaching and learning.

This and other diverse purposes for analogies (such as problem solving, developing mental models, communicating ideas, forming hypothesis, etc.) explain why it is so widely used by scientists (Nersessian, 1992) and in teaching science (Aubusson, Harrison, & Ritchie, 2006).

Despite this, very little has already been investigated about the comprehension and use of these tools by (future) science teachers. In this study, we propose to investigate the following research questions: i) which ideas do pre-service chemistry teachers express about analogies? ii) what relations can we establish between their declarative knowledge and the analogies that they drawn (procedural knowledge)? A discussion of these questions aims at bringing together distinct field knowledge and paving the way for more concrete teacher training in this area.

Methodology

Our sample group was made up of 14 pre-service chemistry teachers, studying in different semesters of their university education. Three of them were in the fifth semester, in which the first discussions about analogies take place; eleven were in their seventh semester and as such, had already experienced discussions about analogies.

In order to reach the aims of investigating how pre-service chemistry teachers understand analogies and the relation between this knowledge and the comparisons they made, they completed a written questionnaire. The questions were focused on their understanding concerning: the concept of analogies; the drawing and use of analogies by scientists; the teacher's aims when drawing and using analogies; the differences between analogies and other comparisons; the basic characteristics of a good analogy to be used in science teaching; the drawing of an analogy to facilitate student's understanding of chemical reactions.

In analysing the data, initially, categories were created based on the main focus of each question, and subcategories were developed based on ideas found in the student's answers. When identifying the type of comparison drawn by the subject, we sought to evaluate if he/she had established relations between the domains (which characterises an analogy), only compared features of the object or descriptive aspects, such as colour, size, shape, etc. (which characterises a mere appearance comparison) or both (which characterises literal similarity). This was done even though the pre-service chemistry teachers had not explicitly expressed the correspondences between the domains.

In order to validate the inferences made by the researchers, a semi-structured interview was carried out in which the pre-service chemistry teachers were asked to: (i) make a critical analysis of the analogy drawn; (ii) map the analogy explicitly (ii) make an analysis of the inferences and considerations brought out by the researcher as to the analogy in question.

In this study, we exemplified the analysis of two cases: that of L2 (a pre-service teacher coursing the 5th semester) and that of L4 (a pre-service teacher coursing the 7th semester), whose ideas about analogies were compared whenever possible.

Results

In table 1, the pre-service chemistry teachers' ideas about analogies are presented according to categories and subcategories defined from the questions. In tables 2 and 3, respective mappings established by the pre-service teachers and/or deduced by the researchers (these are represented in brackets) are presented. In these tables, a solid double arrow represents relational mapping, while a broken double arrow represents mapping of object’s attributes.

Table 1. Categories and subcategories representing the principle ideas of the pre-service chemistry teachers about analogies.

Category	Subcategory	Pre-service chemistry teachers	Examples of answers
Definition of analogy	Explanatory tool for comparing distinct domains	L2	"*It is something used for comparing different concepts, to improve the understanding of one of these concepts.*"
	Explanatory tool for establishing explicit relations between the target and the analogue	L4	"*It is an instrument which can help us explain something unknown to the students, making them able to understand something unknown (target domain) through a made relation (mapping) with something known to them (analogue domain).*"
Scientists' aims for using analogies	Facilitate other people's understanding	L2, L4	"*To improve understanding and accessibility of concepts. It would be a way of giving a better explanation with simpler concepts.*" (L2)
Teachers' aims for using analogies	Facilitate the understanding of something unknown from something known	L2, L4	"*To aid (if the mapping is done) the student's understanding of something to be explained through something which is already known to the students.*" (L4)
Difference between analogies and other comparisons	Comparisons between scientific knowledge and something known *versus* everyday comparisons	L2	"*Analogies are comparisons of a scientific nature with other things, not for example, merely comparing one thing with another thing.*"
	Deep relations *versus* appearance correspondences	L4	"*An analogy is a comparison in which relations are established. However there are comparisons in which the established correspondences are physical and only appearance correspondences.*"

Table 1. Categories and subcategories representing the principle ideas of the pre-service chemistry teachers about analogies (continuation).

Category	Subcategory	Pre-service chemistry teachers	Examples of answers
Types of comparisons elaborated	Potential Analogy	L2	"*The toy 'come and go'*[1] *could be an analogy in relation to the vice versa of the reaction in equilibrium at one time favours forming products, then at another time favours forming reagents.*"
	Mere appearance comparison	L4	"*When we have a man and a woman and they "create" a child, we can also think about chemical reactions, in the end we don't have the same thing as we had in the beginning. In the case of the analogy, in the beginning we have one man and one women creating one child and in reactions we have reagents forming the products. In the relations, there are no relations of feelings and the reagents and the products do not have life.*"
Ideas expressed from the comparisons	Analogies break down	L4	"*In reactions there are no relations of feelings and the reagents and products do not have life.*" (L4 points out where his comparison breaks down).
The characteristics of a good analogy in science teaching	To have a well defined aim	L2	"*That it really has a link with the subject matter, goal, function and that it supports the explanation of the concept.*"
	To allow the making of relations with the target domain.	L2, L4	"*There should be relations established with what you wish to explain.*" (L4)
	To make realities closer or intelligible to students.	L4	"*It should be something of which the student's have an awareness.*"

[1] The "come and go" toy (see figure 1) works in the following way: there is a player on either side of the "come and go" toy, each one holding a handle. In opening their hands the child "pushes" the "come and go " to the other player who makes the same movement to return it. In this game, there are no winners or losers.

Table 2. Comparison mapping established by L2 between a toy "come and go" and reversible reactions.

Target **(Reversible reactions)**	**Mapping**	**Analogue** **(Toy "come and go")**
A chemical reaction may occur both in the sense of forming products, and forming reagents.		"The ball can move in the direction of the reagents as well as in the direction of the products."
[During the state of equilibrium, the rate of the direct and inverse reactions is equal and the formation of neither species prevails.]		If both players use equal force, the ball will stay in the middle and neither direction of displacement will prevail.

Figure 1. Toy "Come and Go". (Available from: velhariadigital.wordpress.com/2012/09/23/vai-vem-trabalhando-biceps-desde-os-anos-70. Access: 05/01/2015)

Table 3. Comparison mapping established by L4 between (having a child) and chemical reactions.

Target **(Chemical reactions)**	**Mapping**	**Analogue** **(Having a child)**
In chemical reactions, reagents combine to form a product.		The relation between a man and a woman results in a child.
The product which has formed is different from the reagents.		The child is different from the man and the woman.

Discussion and Conclusions

An analysis of table 1 allowed us to ascertain that although L2 and L4 conceived the analogies as explicative tools, L2 conceived them in a generic manner as a comparison of two different domains. However, L4 was capable of specifying that these were relational comparisons, and that the relation between the domains should be expressed explicitly. Neither of them was capable of discerning other roles for the analogies, which appears to have reflected in their conceptions about the aims of using and elaborating analogies in science and science teaching; L2 and L4 expressed only their role in facilitating understanding.

The way in which L4 conceived analogies may have been the determining factor for him to point out the characteristics of a good analogy for teaching: the possibility of mapping relations between the analogue and the target and the need of the student to be familiar with the analogue. This may also have been a determining factor, so that he differentiated the analogies from the other comparisons by the deep relations (something that analogies, but not the other comparisons, allow to do. On the other hand, L2 showed only the need to keep in mind the aim of the analogy and its capability of explaining scientific knowledge (unlike other comparisons). This data demonstrates that L4 exhibited more precise declarative knowledge about analogies than that of L2.

Yet, when they were asked to draw an analogy (that is, to express procedural knowledge), L2 was able to establish what we call an "potential analogy" and identify where his analogy "breaks down" – aspects that could not be mapped between the analogue and the target – (see table 2), even though he had not experienced formal discussions about analogies, as L4 had. We called his comparison an "potential analogy" because although he hadn't explained the mappings, these were likely to be relational. On the other hand, although he was able of stating relevant characteristics of a good analogy for teaching, and had differentiated them in an adequate manner in relation to other comparisons, L4 established a comparison of mere appearance (see table 3).

From this analysis, we assume that L2 had already to develop some important skills, such as: imagination, creativity and abstraction. As such, exposing pre-service teachers to theoretic knowledge with the aim of developing their declarative knowledge about analogies may not be enough for supporting the drawing of good analogies in future.

Therefore, we view as essential that, during their initial training period, teachers go through a process of drawing and criticising their own analogies. In doing so, they will be able to develop more practical knowledge about analogies and their use in teaching in a way consistence with the practice of science. This could contribute not only to the drawing of analogies, which were more consistent with scientific knowledge, but also for them to recognise the importance of promoting these occasions in the teaching of science. We believe that these strategies could enrich the teachers' training with more authentic views about analogies and make it more likely that teachers use them with all their potential in teaching.

References

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