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Enhancing Students' Motivation for Learning the Chemical Elements Using Map Puzzles in Secondary Education

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Abstract

The teaching and learning of the chemical elements and their symbols is considered an important part of chemistry programmes in secondary education. However, the large number of elements that make up the periodic table, and the low perception that high school students have of its usefulness, means that different strategies must be used in order to enhance students' motivation away from boring and traditional memorization. In this regard, the use of game-based approaches in chemistry teaching has become accepted as a powerful strategy in recent years. Map puzzles can be useful tools in this learning since they can be used to link the cities and regions of different countries with the learning of chemical elements in a playful manner, thus allowing pupils to learn chemistry by forming the names of cities or other geographical elements from the chemical symbols (for instance, P-Ar-I-S or S-Pa-In). The rules of the game are simple: the map puzzle of a country is presented to students in order to discover the names of its cities from a set of chemical symbols for which only the names are given in a disordered manner. A review of the literature regarding the application of map puzzles to chemistry, and their educational possibilities, is presented in this paper using the geography of Italy as an example. The game is well received by students and engages them more intensely and for a longer period in learning of the chemical elements than traditional memorisation.

Keywords: *chemical elements, educational game, map puzzle, secondary education*

1. Learning the chemical elements

The Periodic Table is considered to be one of the cornerstones of chemistry [1] since it contains essential information about the chemical elements, thus helping chemists to understand why elements react as they do. For this reason, learning of the names and symbols of the chemical elements is considered to be an important part of chemistry programmes in secondary schools. In the last few years, the use of game-based approaches as a tool for enhancing learning has been widely explored in the field of education in general [2] and chemistry in particular [3]. Several fun educational materials for studying the chemical elements have been designed and used by some teachers in order to avoid the boring task of memory learning. The educational possibility of playing with chemical symbols has received considerable attention by educators, with puzzles [4], card games [5], bingos [6], and soccer [7], for example, all having been included in different proposals with the aim of teaching and learning the chemical elements. All these strategies share a common feature, namely that students are motivated to learn the chemical elements in a manner that does not simply involve memorisation.

2. Map puzzles as teaching in context

Context-based science teaching is aimed at relating the science learned by students to their day-to-day life and help them to make sense of the activities they carry out in the classroom or laboratory [8]. Although it is important to take the context used into consideration [9], according to this approach science learning should be related to day-to-day life to ensure that it acquires functionality and attracts students' interest.

The geography of a country is a real-life context that can be used in this study as it allows different regions of the world that the student may be interested in, or wish to visit, to be discovered. In this sense, the maps used to learn geography can be adapted to teach chemistry. An educational map puzzle game teaches children and adults to locate geographical entities of the world on a map. However, map puzzles can also be useful tools in chemistry since they can link different elements of the geography of a country such as states, cities, regions, mountains or rivers, for example, with the

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learning of chemical elements in a playful way. For instance, Am-Er-I-Ca can be formed from the symbols of the chemical elements americium, erbium, iodine and calcium. The main goal of a map puzzle applied to chemistry is to help students learn the names and symbols of the chemical elements. Students are shown a map of a country on which a number of the country's geographical features are indicated but the complete names are not given. The aim is to complete the geographical name by filling in the blank space (one for each chemical symbol). The missing letters in each case are the chemical symbols assigned to the elements indicated underneath each one. Pupils must first determine the symbols that correspond to the names of the elements, and then rearrange these symbols to give the name of the geographical feature. The isotopes of hydrogen (deuterium and tritium) are also used in some cases. One or more letters are included in some names in order to help students. A typical game takes 45 minutes. Although the Periodic Table can be used by students during the task, they should be familiar with chemical names and symbols before playing the game.
A set of map puzzles in different languages (English, Spanish and others) developed by the first two authors of this paper can be found in the literature. The corresponding country, language and geographical features for each puzzle are shown in table 1. These materials allow the teacher to teach the chemical elements in his/her own language and in English, and can therefore be used as bilingual teaching materials.

Table1. Review of map puzzles using chemical elements

Continent	Country	Language	Geographical feature	Reference
America	United States	English	States	[10]
	Argentina	Spanish	Provinces	[11]
	Mexico	Spanish	States	[12]
	Venezuela	Spanish	States	[13]
	Brazil	Portuguese	States	[14]
Europe	Portugal	Portuguese	Regions	[15]
	Poland	Polish	Regions	[16]
	Scotland	English	Regions and cities	[17]
	Norway	Norwegian	Cities	[18]
	Ireland	English	County	[19]
	Germany	English	States and cities	[20]
	England	English	Cities and towns	[21]
	Spain	Spanish	Provinces	[22]
Africa	Africa	English	Countries of the continent	[23]
Australia	New Zealand	English	Capes, bays, straits	[24]
	Australia	English	Urban centres	[25]

3. Purpose of the research

The aim of this paper is to present a new map puzzle based on Italy and the learning outcomes for the chemical elements in a sample of secondary school students. This study proposes the following research question: Are there any differences in the understanding of the chemical elements shown by grade 9 students who have followed this map puzzle relative to others have followed a more traditional teaching method? The hypothesis proposed is that students who have used the map puzzle will remember the names and symbols of the chemical elements better than those who followed a more traditional methodology as they will internalise the elements better when combining them to form the geographical term.

4. A puzzle about Italy's geography context

The aim of this material is to use chemical names and symbols in a game-playing context and involves identifying the names of the 20 regions in Italy, and their capitals, using the set of chemical element names provided (figure 1). These regions and their capitals can be found in the upper and lower boxes in figure 1, respectively.

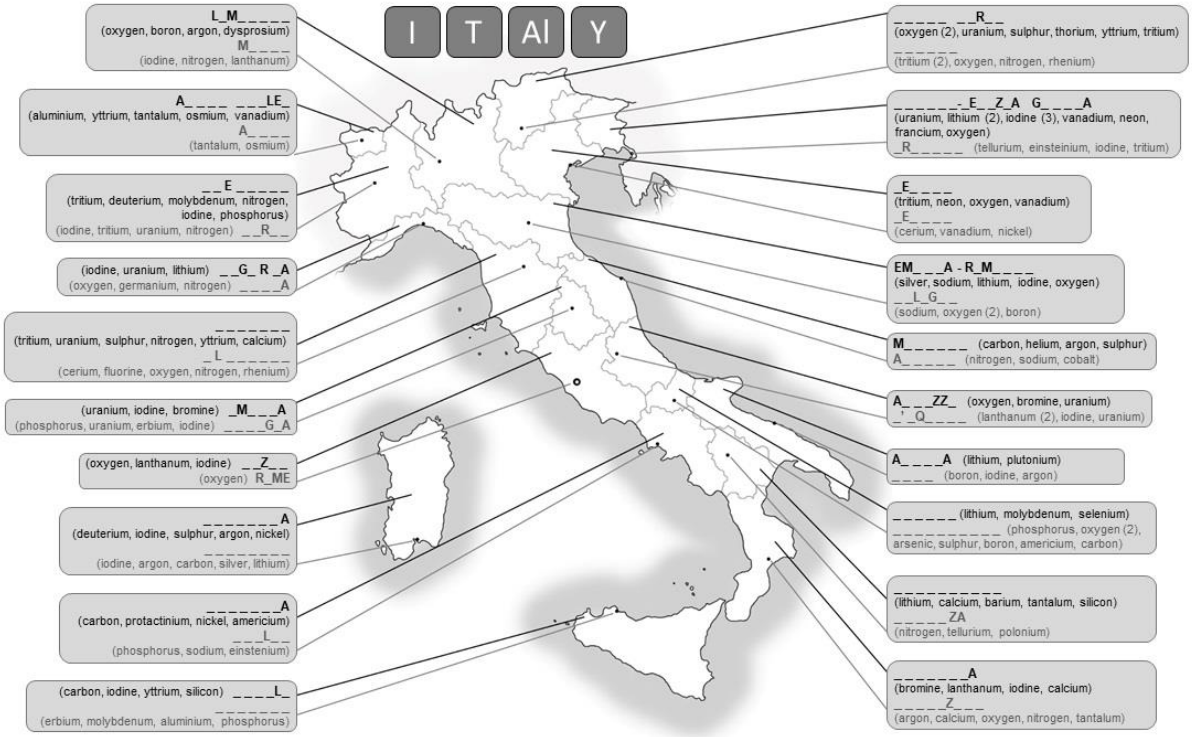

Fig. 1. Map puzzle based on the geography of Italy

The following text, in which the names of the countries that share a border with Italy should be completed using the chemical clues, is presented as an initial example to show the student how the task should be performed: Italy borders _ _ _ _ _ _ (fluorine, radium, cerium, nitrogen) to the West, _ _ _ _ Z _ _ _ _ _ _ (tungsten, sulfur, iodine, erbium, deuterium, lanthanum, nitrogen, tritium) and _ _ _ _ R _ A (sulfur, gold, iodine, tritium) to the North, and _ L _ _ E _ _ A (nickel, oxygen, sulfur, vanadium) to the East. Therefore, the countries that share a border with Italy are FRaNCE, SWIT**Z**ErLaND, AuST**RIA** and S**L**OV**E**Ni**A.**

An additional task, which has not been studied herein but which could take fuller teaching advantage of the study of the chemical elements, could involve a more in-depth study of the natural resources found in Italy.

5. Method

A total of 29 grade 9 Spanish students (15 years) participated in this study, which lasted for 3 hours. Students were assigned to two groups. The experimental group (14 students) completed the puzzle and the control group (15 students) followed the usual teaching method. Both groups were taught by the same teacher (first author). Table 2 summarises the tasks performed by the two groups. Tasks 1 and 2 were carried out on consecutive days. Tasks 3 and 4 were administered as an evaluation one week after the previous tasks; students were not asked to memorise the Periodic Table.

Table 2. Tasks carried out by the experimental and control groups

Task	Experimental Group	Control Group	Use of the Periodic Table	Duration
1	Draw the Periodic Table, indicating the names and symbols of all elements		Yes	1 h
2	Given a list of 40 element names, indicate their symbol, and vice versa	Spanish version of the map puzzle for Italy	Yes	1 h
3	Indicate all the names and symbols of the chemical elements that you know		No	20 min
4	Relate 30 names to 30 symbols for chemical elements presented in two different lists		No	20 min

6. Results

The analysis of task 3 showed that the mean number of chemical elements cited with the correct name and symbol was higher for the experimental group (15.1 elements) than for the control group (3.0 elements). If the results are analyzed by blocks of 10 elements, it is seen that most of the pupils in the control group (93.3%) were unable to cite more than 10 elements, while 57.2% of the students in the experimental group named between 11 and 30 elements (table 3).

Table 3. Results of the task 3

	% grade 9 students	
Number of chemical elements cited with the correct name and symbol	Control Group	Experimental Group
From 0 to 10 elements	93.3	42.8
From 11 to 20 elements	6.7	35.7
From 21 to 30 elements	0	21.5

Figure 2 shows the frequency of students who correctly related each name with its chemical symbol. A bell-shaped distribution, which is displaced towards a higher number of elements for the experimental group (between 18 and 30 elements), was observed in both cases.

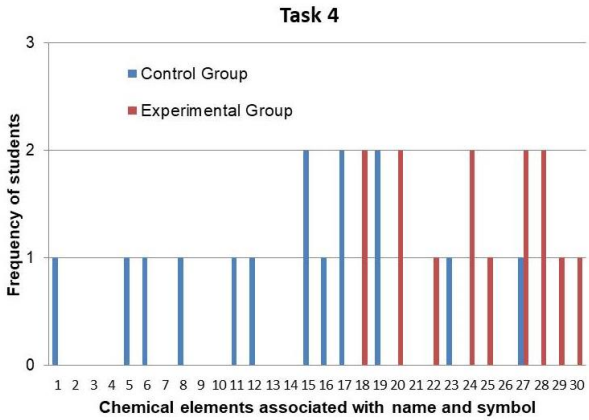

Fig. 2. Frequency of students who correctly related name and chemical symbol in both groups

These findings suggest that the map puzzle is useful for learning the names and symbols of the chemical elements, at least in the short term, thereby confirming the hypothesis initially proposed.

6. Conclusions

The results obtained show that there are differences in the understanding of the chemical elements shown by grade 9 students who followed the educational game (map puzzle) with respect to others who followed a more traditional teaching method, with the former performing better. The game is well received by students and engages them more intensely and for a longer period in the learning of the names and symbols of the chemical elements than traditional memorisation. Finally, we should note

that the learning evaluation was carried out in the short term, therefore the effects of this resource in the medium and long term, which will be analysed in the near future in order to assess the stability of the learning achieved, are currently unknown.

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