Using a word association method to assess knowledge structure of renewable energy sources at primary level

Utilización de un método de asociación de palabras para evaluar la estructura del conocimiento de las fuentes de energía renovables

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Abstract

The word association test is a tool suitable for analysing students' knowledge structure. Using association maps, it can describe the quantitative and qualitative features of the stimulus words and associations as well as their interconnectedness. Our study demonstrates application of the method through the analysis of 4th and 7th graders' conceptual structures related to renewable energy sources. The results showed a more complex conceptual structure resulting from the 7th graders' age, a more complex conceptual system in city learners and a more coherent knowledge in boys. Due to its expressive and informative nature, the word association test is an ancillary evaluation method recommended to teachers as well, with the simplification that in their case it would be sufficient to analyse the quantity and quality of the associations and, based on these, create an association map given the fact that the latter simultaneously shows the nature of the relationships between the stimulus words, too.

Key words: word association test, advantages, disadvantages, renewable energy, knowledge structure

Resumen

El test de asociación de palabras es adecuado para analizar la estructura de conocimiento de los alumnos. Con la ayuda de los mapas de asociaciones, se consigue ilustrar gráficamente las características cuantitativas y cualitativas de sus asociaciones y sus palabras destacadas, además de la correlación entre ellas. En nuestro estudio sobre el uso del método, presentamos el análisis de la estructura conceptual de las energías renovables de alumnos de cuarto y séptimo curso. Los resultados demostraron una estructura conceptual más compleja en los cursos con alumnos de edad más avanzada, un sistema conceptual más exhaustivo en el caso de los estudiantes de ciudad, y conocimientos más profundos en el caso del género masculino. El método de asociación de palabras es un método de evaluación complementario recomendado también para los pedagogos, por su expresividad y su carácter informativo, con la simplificación que puede ser suficiente mediante un análisis cuantitativo y cualitativo de dichas asociaciones. Según esos datos se puede preparar un mapa de asociaciones, ya que al mismo tiempo se presenta el carácter de las relaciones entre las palabras destacadas.

Palabras clave: test de asociación, ventajas, desventajas, energía renovable, estructura conceptual

INTRODUCTION

The word association method has so far been applied at different levels of science education. Within the evaluations made with word association tests the smallest number of studies can be found in the field of analyses of primary school students' knowledge structure. Ercan, Tasdere and Ercan (2010) used this method to study 7th graders' conceptual shift in the field of astronomy. In his research Armagan (2015) found how 6th and 7th graders' metacognitive conceptual system of science research changed after a 5 days' project on research methodology. He thinks that from a data processing point of view, the word association method is time-intensive; however, through conceptual maps, it allows a more transparent and informative evaluation than traditional descriptive statistical procedures in regard to changes in students' conceptual structures. It was primarily the structure of chemistry and biology concepts and its changes that researchers analysed in secondary school students using this test. In their research carried out on 8th and 12th graders Kostova and Radoynovska (2010) reported how they had motivated their students in the course of a special, 12-month-long biology learning period using conceptual maps and the word association method. Kluknavszky and Toth (2009) used this method to study the concepts of groups of 7th through 10th graders related to air pollution. In their study they concluded that the word association method is suitable for mapping students' knowledge structure, monitoring the development of the groups of students' thinking, comparing the various

groups and for exploring misconceptions. In a targeted teaching period Nakiboglu (2008) studied how students' conceptual knowledge of atomic structure changed. He concluded that the word association test is suitable for revealing changes that occurred during teaching.

The highest number of examples of the application of the word association method in evaluation can be found in higher education. Cardellini (2000) studied the knowledge level of first–year students of engineering in the field of general chemistry (pH, mole, binding, state of matter, solution, reaction) before and after a special development training. He thinks that this method helps to map deficiencies and misconceptions among basic concepts. Raviolo, Martine and Aznar (2010) analysed the conceptual shift for chemical equilibrium using word association following a course that applied graphs and a consistent representation of chemical particles. The evaluation confirmed the efficiency of the course, namely that the students' understanding of chemical equilibrium had become far deeper, a fact that could be deduced from the number and nature of correlations in the association maps. In their study of biology teacher trainees Dikmenli, Cardak and Kiray (2011) studied students' alternative knowledge of genes, Kurt and Ekici (2013) that of viruses, whereas Hastürk and Dogan (2016) investigated basic concepts of environmental protection, categorised students into groups based on their alternative knowledge and then drew conclusions pertaining to the application of methods that promote learning.

The above methods confirm the multiple advantages of the word association method in the analysis of students' scientific knowledge. However, they do not describe how it can be used in practice by a school teacher or what its advantage is over evaluation of students' knowledge based on traditional performance assessment tasks. In this study it was our aim to shed light, through an evaluation of the conceptual structure of renewable energy using the word association test, on how this method can be simplified for use by school teachers.

METHODOLOGY

The main objective of our study was to map students' conceptual system and its structure related to the topic of renewable energy. This research is also a precursor to a study of attitudes towards renewable energy, which will allow us to assess primary school students' knowledge, emotions, and attitude related to renewable energy. The study described here helps identify students' knowledge related to renewable energy that represents one part of their permanent knowledge to later serve as a basis for the attitude questionnaire. The method used in this study was the free word association test. During the study we were also actively looking for ways through which a simplified form of the method could be made available to school teachers as well.

In this study we were looking for answers to the following questions: 1) What is the nature of the studied students' concept map of renewable energy and related knowledge in 4th and 7th grades? 2) What correlations can be observed between the various stimulus words? 3) What is the number of the associations given for the stimulus words and how strong is their connection to the stimulus words? 4) What are the most frequent associations and correlations that could function as a basis for the attitude questionnaire? 5) What effect do influencing factors (gender, village, and city) have on the strength, number and quality of the stimulus words and the associated concepts in 4th and 7th grades?

Sample and method

The survey, involving a total of 174 Hungarian students in their 4th and 7th years, was carried out in February and March 2016. The students' levels

of cognitive development and curriculum-dependent prior knowledge of renewable energy are different in the two years, a fact that we presume should be markedly represented in our study, too. As regards the settlement distribution of the study sample, the students came from schools in two cities and two villages not or only slightly larger than 5000 inhabitants each (Table 1).

Table 1. Distribution of the study sample

	village	city	grade 4	grade 7
boys	38	41	46	33
girls	53	42	44	51
total	91	83	90	84

The method applied in the study was the free *word association test*. The teachers were informed of the purpose of the association test, as well as the mode and time of the survey, before the assessment. They introduced the tests in the 4th and 7th grades that they were teaching and forwarded them to the teachers who later evaluated them. In the word association test learners had to attach associations to various stimulus words. In our study the learners had 2 minutes at their disposal for each stimulus word to describe the associations related to the given stimulus, which they had to list under one single column. An important factor in choosing the stimulus words was that each of them should be covered in the curriculum.

The stimulus words we studied were the following: *renewable energy, energy saving, power station, and heating*. During evaluation of the word association tests both the associations attached to the various stimulus words and the strength of the relationship between the stimulus words can be studied. The strength of the relationship between the stimulus words can be expressed with the relatedness coefficient (RC) suggested by Garskof and Houston.

Calculation of the Garskof-Houston relatedness coefficient is represented through an example taken from our study (Garskof & Houston, 1963). As mentioned before, the four stimulus words used in the survey were *renewable energy, energy saving, power station, and heating*. All learners wrote a related list of associates for each stimulus word. The following is an example written by a 7th-grader:

> "Renewable energy: power, wind turbine, water, sun, solar cell. sea, hydroenergy, nuclear energy.
>
> Energy saving: saving money, turn off the power, solar cell, reasonableness, power station, wind turbine
>
> Power station: water, wind, sun, coal, heating, electricity,
>
> Heating: furnace, stove, warm, coal, wood, gad, convector, winter, cold, underfloor heating."

The value of RC needs to be calculated for every pair of stimulus words (renewable energy – energy saving, renewable energy – power station, renewable energy – heating, energy- saving – power station, energy saving - heating, and power station – heating).

Let's take the example of the calculation of the RC value for the above learner's pair of stimulus words: renewable energy - energy saving. First we examine to which stimulus word the learner provided the most associates. In this case this is the list regarding renewable energy, which contains 9 elements including the stimulus word itself while the list regarding energy saving only has 7 elements. Following Garskof and Houston (1963), we progress toward the stimulus word starting the ranking of the associates at the end of the list that has more elements (in our example this is nuclear energy, given the rank number 1) and the stimulus word itself is also assigned a ranking (in our case this number is 9). Then the elements of the list made up of the second member of the pair of stimuli are also ranked. The stimulus word (energy saving) here is given the ranking of the previous stimulus word (9), and then we rank the associates in the list in descending order (wind turbine is given the ranking 3). As the second list contains fewer elements (7, including the stimulus word), there will be no associations with the rankings 1 and 2. Having ranked all the elements, we examine whether there are identical associates (in our example, wind turbine and solar cell are associates for both stimulus words) in the lists for the two stimulus words and substitue their values in Garskof and Houston's (1963) RC formula (Table 2). In the numerator of the formula we have the sum of the products of the ranks of the identical associates of the examined stimulus words (in our example, for wind turbines it is 7x3, plus 4x6 for solar cell = 45). In the denominator of the formula we have the sum of squares of

the elements of the longer list minus one (in our case, the sum of squares of the 9 elements for renewable energy is 295, minus 1= 294). This means that for the pair of stimulus words the value of RC, which expresses the strength of the interrelatedness of the two stimulus words, is 0,15 (Table 2). We calculate the RC value for each pair of stimulus words for every child and obtain the mean RC values for the examined pairs of stimulus words for the given group of learners. We use these values to construct the map of correlations for the given stimulus words for the particular group of learners according to data on the strength of relatedness defined by Cardellini and Nakiboglu (2008) (Table 3)

Table 2. Calculating relatedness coefficients (RC) in cases of different numbers of associations

Associations with stimulus word A	Rank	Associations with stimulus word B	Rank	Garskof–Houston-relatedness coefficient
Stimulus word (A) RENEWABLE ENERGY	9	Stimulus word (B) ENERGY-SAVING	9	$RC = \dfrac{\overline{A \cdot B}}{\sum n^2 - 1}$
power,	8	saving money,	8	
wind turbine,	7	turn off the power	7	**RC = 7x3 (wind turbine)+ 4x6(solar cell) =0,15**
water,	6	solar cell,	6	
sun,	5	reasonableness,	5	$9^2 + 8^2 \ldots + 2^2$
solar cell	4	power station,	4	
sea	3	wind turbine	3	
hydroenergy	2			
nuclear energy	1			

RESULTS AND DISCUSSION

Relationship between stimulus words

Our first step was to construct concept maps for stimulus words based on the learners' responses. Before this step, we first determined the strength of Garskof–Houston's relatedness coefficient between the stimulus words for every learner and then calculated averages for the obtained results.

We took the relatedness coefficients determined by Cardellini and Nakiboglu (2008) as a starting point for making conceptual networks (Table 3.)

Table 3. Strength and mode of notation of the relatedness coefficients in the concept network

Value of relatedness coefficient	Strength of relatedness	Notation
0,03 – 0,06	weak	
0,07 – 0,10	medium	
0,11 –	strong	

In our study we first looked for answers to the questions about the nature of *the concept network of 4th and 7th graders involved in the study related to renewable energy and related knowledge on the one hand,* and the *kind of relationships that could be observed between the stimulus words, on the other*. To answer these questions, we constructed the concept map of the stimulus words based on Garskof–Houston's relatedness coefficients. (Table 4, Figures 1 and 2).

Table 4. Relatedness coefficient values of stimulus words in 4th and 7th grades

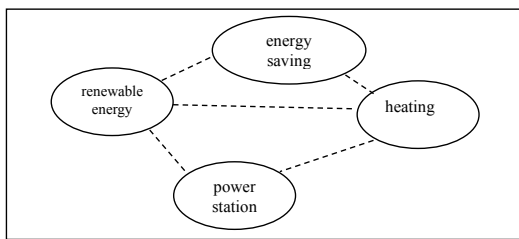|	renewable energy		energy saving		power station		heating	
	Grade 4	Grade 7	Grade 4	Grade 7	Grade 4	Grade 7	Grade 4	Grade 7
renewable energy	-	-	0,06	0,08	0,05	0,11	0,03	0,01
energy saving			-	-	0,02	0,04	0,03	0,01
power station					-	-	0,03	0,02
heating							-	-

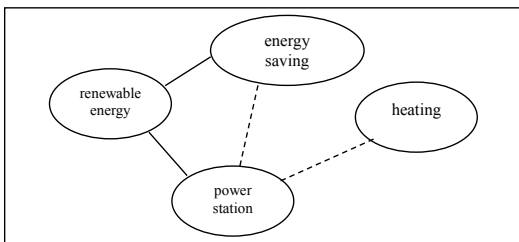**Figure 1. 4th graders' conceptual network of stimulus words**

Figure 2. 7th graders' conceptual network related to stimulus words

In terms of the differences between 4th and 7th graders, the difference in knowledge in the given topic between the two age groups becomes conspicuous. While there is one more connection (5 altogether) in the group of 4th graders, all of them fall within the weak category. In 7th grade there are a relatedness of renewable energy and power station and a medium strength relatedness between energy and energy saving. The reason for the difference between the two age groups is assumed to be the following: while the ratio of concepts of everyday life and related knowledge (e.g. heating) is greater than that of scientific concepts in the conceptual system of younger learners (4th graders), (or rather, they tend to use everyday language to formulate their conceptual knowledge), their 7th-grade counterparts exhibit several well-related scientific concepts that enhance the strength of relatedness between stimulus words (due to more abstract thinking and the formal operational stage of cognitive development).

Table 5. Distribution of relationships of various strengths across stimulus words in the two age groups

	Strong		**Moderately strong**		**Weak**		**Total**	
	7th grade	4th grade	7th grade	4th grade	7th grade	4th grade	7th grade	4th grade
City	1	-	1	-	2	5	4	5
Village	-	-	1	-	1	3	2	3
Boys	1	-	1	-	1	2	3	2
Girls	-	-	-	-	1	3	1	3

Among the influencing factors we examined the differences between city and village students in terms of strength and quantity of relatedness between the stimulus words (Table 5). Thus it is clear that city learners outdo their village counterparts in both age groups both from a qualitative and a quantitative point of view in terms of their knowledge of the concepts that we studied on renewable energy. This can likely be attributed to the difference in the learners' levels of education (infrastructure, teaching methods applied, etc.) in city and village schools as well as to differences in the social backgrounds of the learners in the two types of settlements. As surmounting village students' disadvantages is a very important endeavour, finding the causes of the above differences requires further investigation. Across genders, the greatest number of relationships between stimulus words occurred in the boys' thinking in 7th grade, whereas in 4th grade it was the girls who produced the most such relationships. From a quantitative point of view, this is not a significant difference,

Relationships between stimulus words and associations

Conceptual networks are a good reflection of the strength of relatedness between the studied stimulus words, however, from the aspect of our investigation, it is more interesting to see the associations through which these concepts are linked to one another. By examining this question we

can obtain an answer to the question: *what conclusions can be drawn about the strength, quality and nature of the relatedness of the stimulus words and their associated concepts?* To demonstrate this, we calculated the relative frequency of associations provided for every stimulus for both grades. We constructed the conceptual networks based on the relative frequency values presented in Table 6 (Kluknavszky & Tóth, 2009). The strongest relatedness values represent a relative frequency of 76% or over of all associations. We decreased this value by 15% at a time. Due to the great number of connections and their poor relatedness strength relative to the others we did not represent the lowest 15% in the conceptual map. Thus the associations occurring in the conceptual networks represent the most frequent concepts related to stimulus words that also constitute part of students' permanent knowledge on a topic. It is these concepts, too, that represent the nodes of the survey on environmental attitudes around which the questionnaire's statements can later be organised.

Table 6. Strength and notation of relative frequencies in the conceptual network containing associations

Relative frequency of associations	Strength of the relatedness	Notation
below 0-15 %	very weak	not presented graphically
16-30 %	weak	····························
31-45 %	medium	- - - - - - - - -
46-60 %	medium strength	—————
61-75 %	strong	═════
over 76 %	very strong	▬▬▬▬

After calculating the relative frequencies of the associations provided by the students for 4th and 7th grades, we constructed association maps. We could clearly see (Figures 3 and 4) the predictable picture that 4th graders possessed fewer associations and relationships in accordance with the level of their cognitive development and knowledge. With 4th graders the strength of the associations related to the stimulus word power station failed to reach the relative frequency of 16%, necessary to be represented on a chart. This led us to conclude that the concept of power station has not yet become incorporated into 4th graders' conceptual system with proper efficiency. In contrast, 7th graders seemed to possess more comprehensive knowledge and signalled points of connection also between stimulus words that were closely linked to one another. In terms of strength of associations, the stimulus word 'heating' deserves mention in both grades - it is apparent that students can build the strongest associations with heating that is present in their everyday lives. The results connected to heating presumably suggest that students' experience derived from everyday life has a stronger influence on their environmental awareness. including their energy awareness, than their knowledge learnt formally at school as subjects.
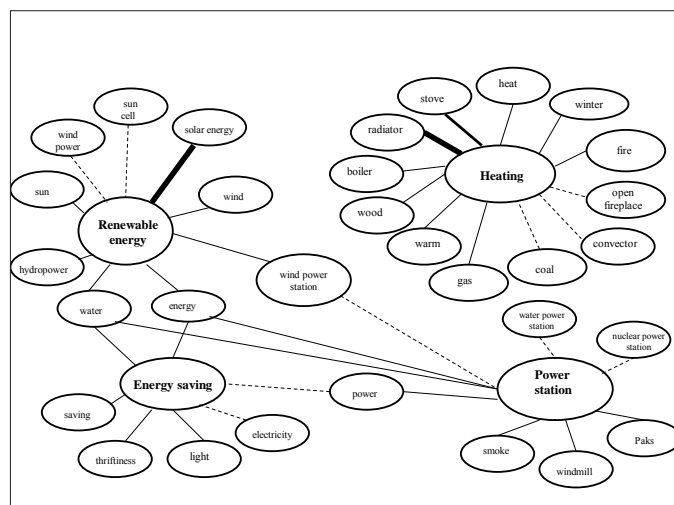

Figure 3. 4th graders' conceptual network in view of the relative frequencies of the associated concepts
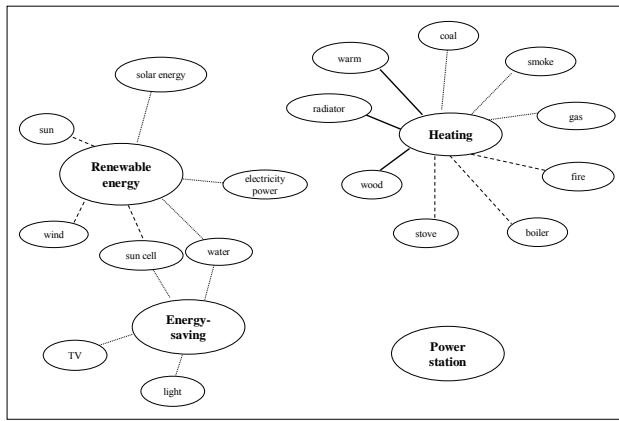
Figure 4. 7th graders' conceptual network in view of the relative frequencies of the associated concepts) (comment: Paks is a city in Hungary with a nuclear power station)

In terms of the number of associations there was a preponderance from learners living in big cities compared to those living in villages – the possible reasons for this have been mentioned before in connection with stimulus words.
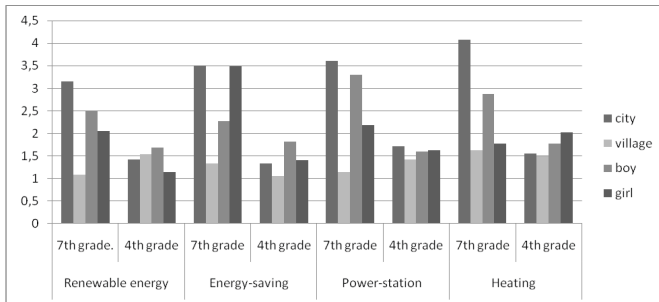

Figure 5. Relative frequency of the types of associations related to various stimulus words in 4th and 7th grades

We examined the number of different types of concepts provided by the students for the various stimulus words (Figure 5, Table 7). In terms of the relative frequency of the produced association types there was a significant difference between 4th and 7th graders as well as city versus village 7th graders for each stimulus word. At the same time, there was no significant difference between the numbers of association types of 7th and 4th graders living in villages. In terms of gender, 7th grade girls mentioned significantly more concepts for the stimulus word energy efficiency while 7th grader boys provided more associations for the stimulus words power station and heating. The advantage shown by 7th graders regarding the influencing factors can be observed here, too, and can be attributed, also in this case, to these students' more advanced cognitive deveeloopment and prior knowledge.

Table 7. Significance of differences between the frequencies of occurrence of the association types produced for stimulus words(n: all association types produced)

	Renewable energy (n=198)		Energy-saving (n=176)		Power-station (n= 238)		Heating (n=228)	
	7th grade (n = 198)	4th grade (n =142)	7th grade (n = 176)	4th grade (n = 123)	7th grade (n = 224)	4th grade (n =132)	7th grade (n = 187)	4th grade (n = 156)
City-village	t=10,58 p=0,000		t= 12,18 p=0,000		t= 9, 43 p=0,000		t=4, 39 p=0,000	t=4, 76 p=0,000
Gender			t=8,45 p=0,013		t=10,24 p=0,004		t=3,34 p=0,021	

We also evaluated the association types from the aspect of the total number of times they were mentioned (Table 8). We found significant differences in terms of the relative frequencies of mentions of the associations between 7th and 4th graders for each stimulus word. These results also revealed the advantage of learners from cities due to reasons described above. In the field of mentions of all associations it was only with the stimulus word power station that boys produced more related concepts than did girls compared with types.

Table 8. Significance of the differences between the relative frequencies of the association types of mentions

	Renewable energy (n=981)		Energy-saving (n=809)		Power-station (n=955)		Heating (n=1527)	
	7th grade (n = 586)	4th grade (n = 395)	7th grade (n = 579)	4th grade (n = 230)	7th grade (n = 656)	4th grade (n =299)	7th grade (n = 892)	4th grade (n = 625)
City-village	t=11,29 p=0,000		t= 6,25 p=0,000		t= 11,84 p=0,000		t=5,54 p=0,000	t= 3,14 p=0,002
Gender					t=2,38 p=0,01			

Based on the associations studied, in the given age groups, we observed the formation of the circle of common concepts that occurred most frequently in relation to renewable energy and that were part of the students' prior knowledge. These shared concepts could later provide the basis for a questionnaire for an environmental attitudes study in the given topic. These concepts are water, wind, sun, power station, sun cell, solar power, wind power, efficiency, electricity, and lamp.

Our research has given a picture of the studied population's knowledge structure for renewable energy, the quantitative and qualitative features of the concepts related to the topic and their network. Application of the free word association method also revealed concepts and interrelationships that we could not have gained information about from the closed and open-ended assignments of usual performance assessment batteries. Our evaluation has also shown what sources learners' topic-related knowledge comes from, and what the role of the school and everyday experience is in shaping any given knowledge. From this we can draw methodological conclusions, too, including the fact that, in the process of learning about things, it is necessary to map learners' prior knowledge that comes from everyday practice and incorporate it into their knowledge acquired during their school education. All this is signalled visually by the method of word association through the use of conceptual maps, which provides a clearer, more intelligible picture of leaners' knowledge compared with traditional evaluation. One advantage of the method is that data recording takes place quickly, within a couple of minutes, however, processing the data is time-intensive, making it favourable for processing small sample sizes. The analysis presented here is an evaluation procedure recommended for researchers, scientifically encouraged in its entirety and form. However, since a single association map can provide us with information (e.g., structure of the given concept, the relationship between the elements of a concept, level of understanding of a concept, its place in learners' knowledge, deficiencies related to a concept, possible misconceptions, conclusions for teaching methodology resulting from deficiencies) which would hardly, or not at all, emerge from traditional performance assessment, it is advisable for teachers to perform the method of assessment in a rationalised, less time-consuming way. For a teacher the more informative part of this evaluation is the map that also contains associations since it contains the interconnectedness among the stimulus words, too, and shows what associations lead to these connections. This is not shown by the map illustrating only the relationship between the stimulus words. The association map also reveals the most frequent concepts related to the stimulus words, again not shown on the map of stimulus words. This is why teachers do not need to get involved in time-consuming calculations of relatedness coefficients. Instead, they should enter the association types produced by the learners into an excel table (if a student has mentioned the association in question, they are given a 1). Then,then, using the excel programme's relevant function, teachers quickly calculate the relative frequency of each association and construct the association map based on the above value limits. Because the word association method does not reveal how a student defines a concept it is

recommended that the method should be used in combination with the relevant assignments and evaluations of the traditional performance assessment.

CONCLUSIONS

The main purpose of the study was to desrcribe the application of the free word association method in the analysis of learners' knowledge structure. The topic we chose for our analysis was 4th and 7th graders' conceptual systems related to the concept of renewable energy, which we evaluated from the aspect of the role of age as well as of gender and size of settlement. The word association test has helped in demonstrating that, as learners age, their knowledge turns into a more and more complex structure comprising of more and more concepts and connections in the given topic. In terms of settlement size, the knowledge of city children proved to be more complex, which can presumably be attributed to the difference in the learners' cultural and social background as well as the more favourable infrastrucure and teaching methodology applied in city schools. In our analysis we first constructed the network of connections among the stimulus words followed by the descripiton of the relationship between the stimulus words and the associations attached to them as well as the quantitative and qualitative characteristics of the associations. We concluded here, too. that the word association method is descriptive, simultaneously giving a good overview of students' knowledge structure, and its quantitative and qualitative aspects. However, it is time-intensive and hence should be applied on small sample sizes. Yet, due to its informative character, it can be recommended as a method of evaluation to teachers, too, who can use it at school to assess students' current knowledge or the changes in that knowledge. To teachers we recommend a simplified, less time-intensive version of the free word association test, which considers only the analysis of the associations and the connection between the stimulus words and the associations. In this case the maps containing the associations simultaneously make clear the strength and nature of the connections between the stimulus words, too. Thus the word association test can complement the traditional, descriptive statistical analysis of school evaluation.

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Misconceptions sequencing the chemical processes in Daniell and electrolysis cells amongst first-year science and mathematics education university students

Conceptos alternativos de los estudiantes sobre los procesos químicos en las células de Daniell y de electrólisis

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Abstract

This study aims to analyse a number of misconceptions amongst first-year students from the Department of Mathematics and Science Education, Academic Year 2013/2014, at the University of Tadulako, Indonesia. The purpose is to explore the students' understanding of the concepts and the processes involved in electrolysis cells. In addition, the use and purpose of a salt bridge in these cells are considered. A two-part test instrument was used to obtain the data. The test instrument involved a paper for the students to answer. The paper encompassed a series of stages for the mechanisms and processes that take place in (i) the Daniell cell (Zn-Cu) and (ii) the electrolysis cell for molten NaCl. Both processes were summarised into seven stages. Each stage consisted of three scientific illustrations for the students to choose from, with only one considered to be chemically correct. In addition, the students were asked to give a brief description of the mechanism they thought occurred at each stage and why. The results demonstrated that there was a higher level of misconception within the students' understanding of the electrolysis cell of molten NaCl (44%) when compared to their understanding of the Daniell cell (31%). For the Daniell cell, the half-reduction reaction (51%) was the most common misconception amongst the students, whilst for the molten NaCl cell ion migration (65%) appeared to be so.

Key words: misconceptions, chemistry learning, Daniell cell, electrochemistry, electrolysis cell, molten NaCl, salt bridge.

Resumen

Este estudio tiene como objetivo analizar una serie de conceptos erróneos entre los estudiantes de primer año del Departamento de Matemáticas y Educación Científica, (2013/2014), en la Universidad de Tadulako, Indonesia. El propósito es explorar la comprensión en los estudiantes de los conceptos y los procesos involucrados en las células de electrólisis y además, el uso y propósito de un puente de sal en estas células, también. Se utilizó un instrumento de prueba de dos partes para obtener los datos. Se hicieron una serie de pasos para determinar los procesos en la célula de Daniell (Zn-Cu) y la célula de electrólisis con el NaCl, fundido. Ambos procesos se resumieron en siete etapas, cada una consistió en tres ilustraciones científicas para los estudiantes, a elegir. Además, se pidió a los estudiantes que proporcionaran una breve descripción del mecanismo que pensaban que había ocurrido en cada etapa y por qué. Los resultados demostraron que había un mayor nivel de concepción errónea dentro de la comprensión de los estudiantes de la célula de electrólisis de NaCl, fundido (44%) en comparación con su comprensión de la célula de Daniell (31%). Para la célula de Daniell, la semireacción de la reducción era el error más común entre los estudiantes.

Palabras clave: conceptos alternativos, aprendizaje de la química, célula de Daniell, célula de electrólisis, NaCl fundido, puente salino.