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An examination of the knowledge structure of primary and secondary school students regarding air pollution by means of word association test

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ABSTRCT

We examined the conceptual structures of 7th to 12th grade students related to air pollution by means of word associations. Students were asked to write their associations for the following stimulus words: greenhouse effect, ozone hole, acid rain, carbon-dioxide, sulphur-dioxide, ozone. The association networks attached to each stimulus word generally become richer and richer up to grades 9 and 10, than a decrease can be observed regarding the frequency of associations. At the same time in the conceptual networks, relations referring to misconceptions and misunderstandings also occur apart from the contextually correct relations, out of which the strongest one is the relation of ozone – ozone hole in almost every school year.

1. Introduction

The word association method reveals the respondent's model of thought about the world, his/her oral memory, the process of thinking, his/her emotional state and personality (Sinopalnikova and Smrz, 2004, cited in Nakiboglu 2008). The method also proved to be suitable for studying the knowledge structure of students. When applying the method of word associations students are given the most important concepts of a topic as stimulus words and they have to associate new words or concepts with them in the given time. The intensity of the relation between the stimulus words is determined by a relatedness coefficient which is calculated on the basis of the common associations and their order. Word association tests have been implemented in science for approximately 50 years. Several examples of such examinations have been published in international journals. A lot of research shows that the word association test is an effective technique for examining the pre- and post-knowledge, misconceptions as well as the process of conceptual development and conceptual change. (Ercan, Tasdere and Ercan, 2010; Hovardas and Korfiatis, 2006). Cachapuz and Maskill (1987; cited by Nakiboglu, 2008) investigated the students' prior knowledge of reaction kinetics using the word association method. It has been shown that students have this kind of prior knowledge and as a result of teaching, their conceptual system became more complex. Cardellini and Bahar (2000; cited by Nakiboglu, 2008) used word association tests for studying first year engineering students' misunderstandings and misconceptions regarding general chemistry concepts. Nakiboglu (2008) investigated the change in the characteristic conceptual structure of the student group using word association tests taken before and after teaching the topic of atomic structure. Timur (2012) examined the knowledge structure and the misconceptions of future kindergarten teachers concerning the topic of force and motion. Öner Armağan (2015) studied the changes of the knowledge structure of primary school students at the beginning and at the end of a project dealing with science in general, based on constructivist methods. Özata Yücel and Özkan (2015) analysed the knowledge structure and misconceptions of 12-14-year-old students regarding basic ecological concepts. Malmos, Jász and Markóczi-Revák (2017) analyzed the 4th and 7th grade students' conceptual structures related to renewable energy sources by using the word association method. In their study, they demonstrate how school teachers can simply use this method.

Besides several international examples the implementation of the method has been spreading in the circles of Hungarian researchers as well and the number of similar studies in the Hungarian academic literature has also increased. Kluknavszky and Tóth (2009) examined the concepts of primary school students in their 7th and 8th grade and secondary grammar school students in their 9th and 10th grade about air pollution (carbon-dioxide, sulphur-dioxide, ozone, nitrogen-oxides, greenhouse effect, the hole in the ozone layer, acid rain) with the method of word associations. Tóth and Sója-Gajdos (2012)

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analysed the relation of concepts of energy resources (fuels,non-renewable energy resources, renewable energy resources, coal, crude oil, nuclear energy) among students studying in various school types (vocational, vocational secondary and secondary grammar schools) from grades 7 to 12. Kádár and Farsang ciations given to the stimulus words were presented in a spectacular word cloud. Daru and Tóth (2013) examined kindergarteners' conceptual system about the weather with the method of word association test and knowledge space theory combined with phenomenography. The children's answers, who still could not read or write, were recorded in the form of a structured interview. Kádár and Farsang (2014) also conducted a comparative analysis on the misconceptions of university students concerning geography. They compared the results of two groups of students – one majoring in geography and the other majoring in social sciences - regarding the topics of global warming and the inner structure of the Earth. They were presented with six stimulus words in the topic of global warming: global warming, greenhouse effect, solar radiation, ozone layer, carbon-dioxide, the melting of the local and polar ice caps. Malmos and Revákné (2015) mapped the misconceptions of students in their 7th and 8th grade about biological concepts using the method of word associations.

2. Objectives

The examined concepts (greenhouse effect, a hole in the ozone layer, acid rain, carbon-dioxide, sulphur-dioxide, ozone) have previously been used in a small-scale survey, in which the knowledge structure of groups of 7th- to 10th-grade students was analysed with the method of word association test (Kluknavszky and Tóth, 2009). During the course of our study, we posed the following research questions:

1. Are there any differences in the knowledge structures (conceptual networks) of different student groups?
2. Are there any differences in the association maps for a specific stimulus word?
3. What type of misconceptions and misunderstandings can be explored by means of word association test?

3. Sample and method

(2012) studied the misconceptions of primary and secondary school students regarding the subject of geography, among them the concepts of greenhouse effect and global warming. During the course of their research, they also used the method of word association test. The asso

553 students (117 students in their 7th grade, 120 in their 8th grade, 72 in their 9th grade, 100 in their 10th grade, 73 in their 11th grade and 71 in their 12th grade) from a model school of a provincial university participated in the study. Teachers teaching science subjects assisted in the implementation of the study. The actual study was preceded by practice activities during which the students could get acquainted with the method of word association test.

During the word association test, the students were given a booklet, in which the stimulus words were written on separate pages. They then had to write further concepts under each stimulus word. They had one minute to write further associations under each stimulus word. When they finished one concept, they could turn to the next page, but they were not allowed to return to the previous ones.

In order to determine the strength of connections between the stimulus words we calculated the Garskof–Houston relatedness coefficient (abbreviated as RC) (Garskof and Hoston, 1963). A RC was calculated between pairs of stimulus words for each student. Table 1 shows and example for this calculating process: A student response to the stimulus word (A) ozone hole was the following sequence of associations: global warming, CO2, exhaust gas, factories, UV radiation, skin cancer. To the stimulus word (B) greenhouse effect: global warming, ozone hole, greenhouses, growing of vegetable. The rank order was determined by the longer sequence of associations (in our case: stimulus word (A) ozone hole). In the two lists, there are 2 common associated words (ozone hole, and greenhouse effect). We calculated RC according to the formula in the Table 1. In the numerator of the formula we have the sum of the products of the ranks of the identical associates (in our example, for ozone hole 7 x 5, plus 6 x 6 for global warming). 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 7 elements).

Table 1 An example for the calculating relatedness coefficients (RC)

Stimulus word (A)	Rank	Stimulus word (B)	Rank
OZONE HOLE	7	GREENHOUSE EFFECT	7
global warming	6	global warming	6
CO_2	5	ozone hole	5
exhaust gas	4	greenhouses	4
factories	3	growing of vegetable	3
UV radiation	2		
skin cancer	1		

$$RC = \frac{\bar{A} \cdot \bar{B}}{\sum n^2 - 1}$$

$$RC = \frac{7 \times 5 + 6 \times 6}{7^2 + 6^2 + 5^2 + 4^2 + 3^2 + 2^2 + 1^2 - 1} = 0{,}51$$

The value of RC may be between 0 and 1, the higher the number, the stronger is the relation between the two concepts. We calculated the average of the individual relatedness coefficients for each student group. Based on these values we drew the conceptual net for each grade. In order to reveal the meaning of the relation between the stimulus words and the possible misconceptions in the conceptual net, we looked at what common associations were given for a given pair of concepts by the students. We analysed the relative frequency of the associations assigned to the stimulus words for each grade and bearing that in mind we drafted the association map of each group.

4. Result

In the following section of this paper, we will present and analyse the most frequent associations, association and

conceptual networks obtained for the student groups of grades 7th to 12th.

The most frequent associations obtained for the individual stimulus words

The most frequent associations assigned to the individual stimulus words are presented in the association networks based on their frequencies. It is the way how the position of a concept is changed in the cognitive scheme as school education progresses that can be described in this way. The relation between the stimulus word and the association is certainly not always relevant contextually. It may happen that the association applied for a stimulus word is influenced by other factors such as phonetic similarity, frequent co-occurrence. In the schematic illustration the cut-off points were the following: 20%, 40% and 60%. The relative frequency from 20% to 39% was marked with a broken line, the frequency from 40 to 59% was marked with a thin continuous line and that over 60% was marked by a thick continuous line.

The associations connected to the concept of carbon-dioxide is shown in Figure 1. The relative frequency of the associations has not reached 40% in any year. Marking with a formula among the associations appears everywhere except for grade 7. The most associations can be seen in the case of grade 10 and the fewest in the case of grade 12, where it is only the formula that appears. In the case of several years the word 'gas' meaning a state of matter and the association of carbon and oxygen referring to the structure can be observed.

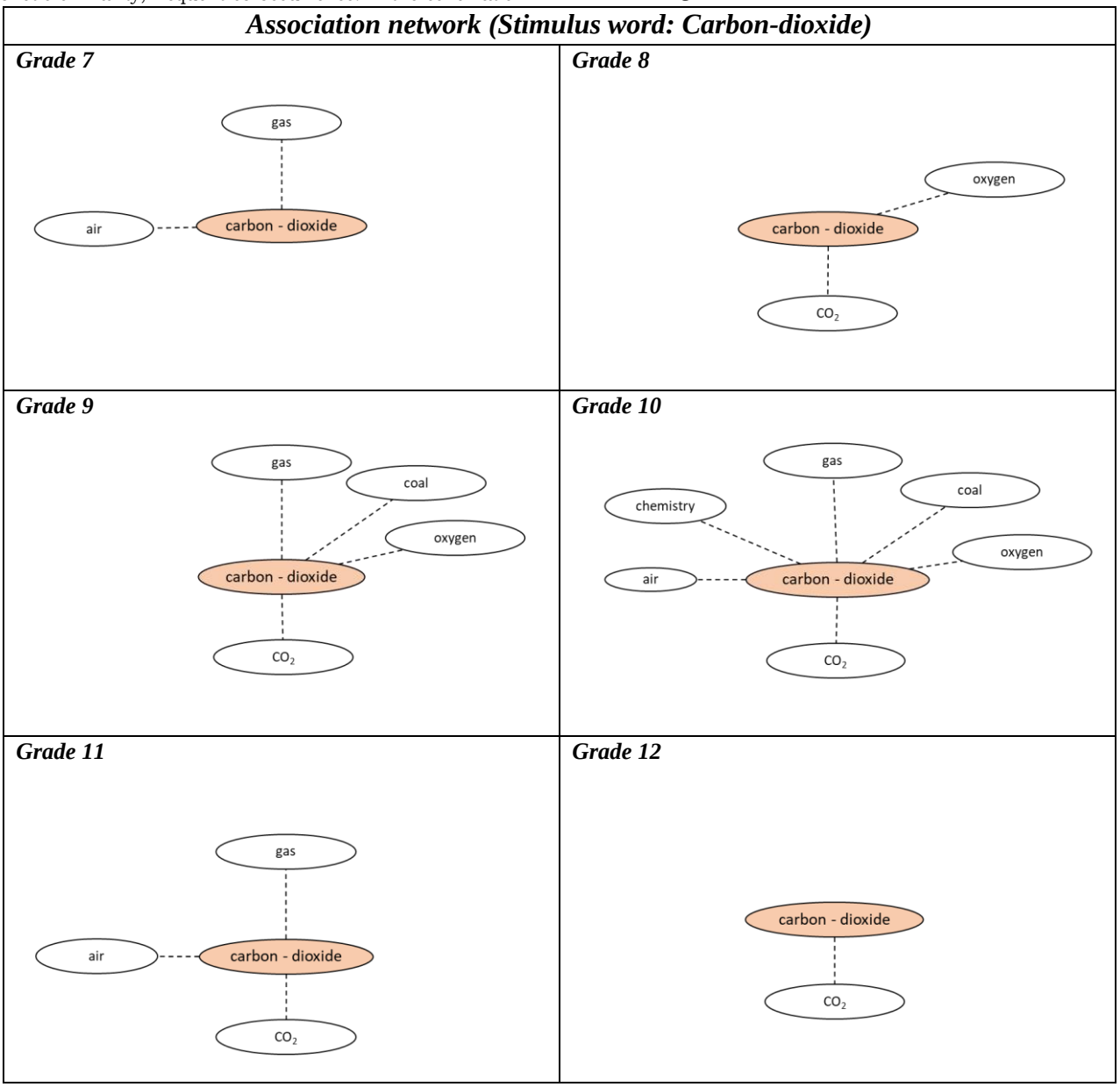


Figure 1: The most frequent associations obtained for the concept of „carbon-dioxide" (broken line: 20 – 39 % relative frequency; thin line: 40 – 59 % relative frequency; thick line: ≥ 60 % relative frequency).

In Figure 2 we presented associations connected to sulphur-dioxide. We can see that an identical or even higher number of associations, in the case of each grade, may be presented compared to that of carbon-dioxide. The most associations in grade 10 and the fewest associations in grade 12 could be observed here, too. In the case of several grades, associations referring to 'gas' and 'poisonous' demonstrating physical and physiological qualities, the words 'sulphur' and 'oxygen' referring to the composition and chemical associations can be observed. The association of 'compound' can only be noted in

grade 8 and 10. Marking sulphur-dioxide with a formula and associations referring to acid rain, its environmental effect only occur in grade 12.

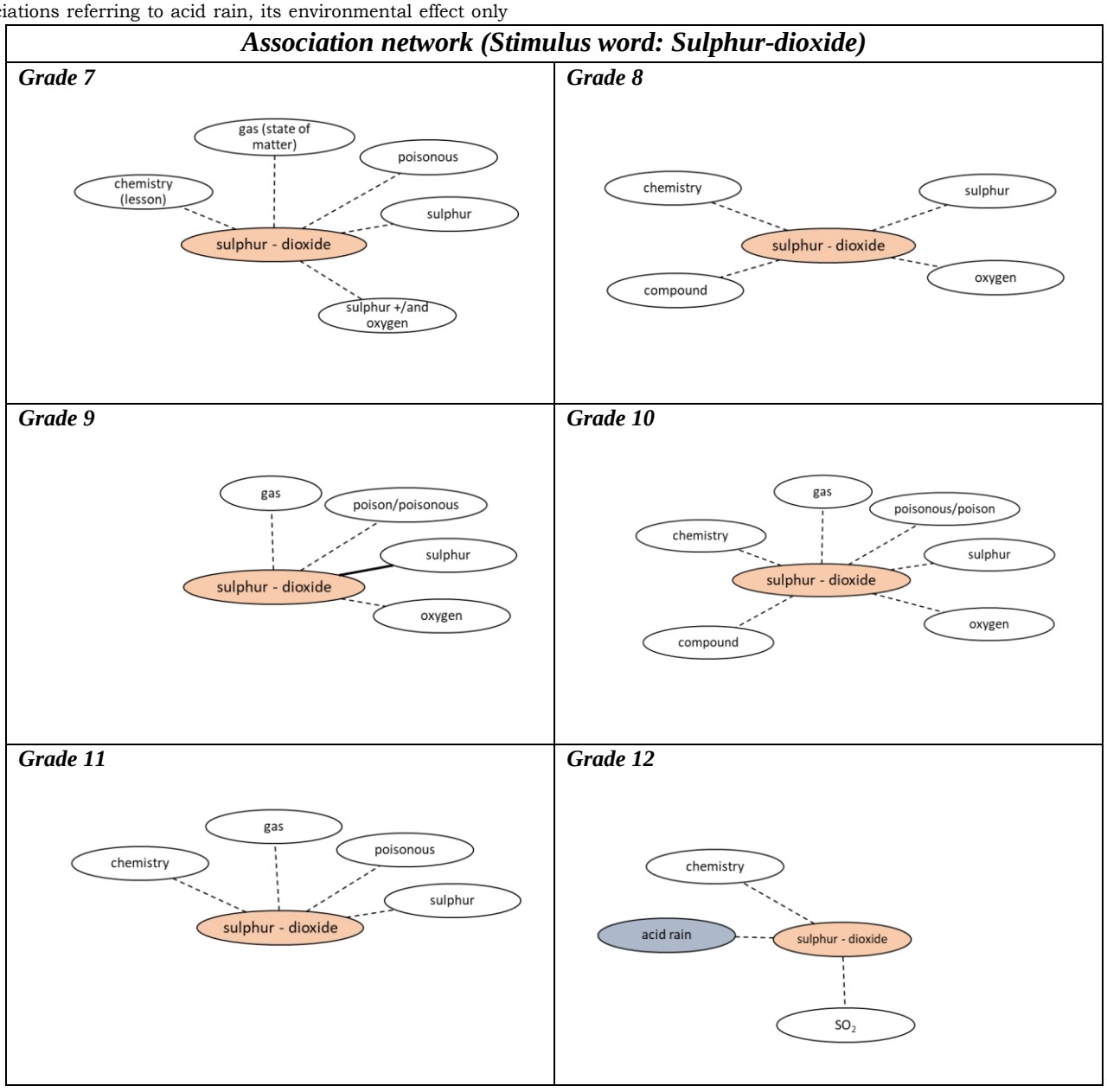
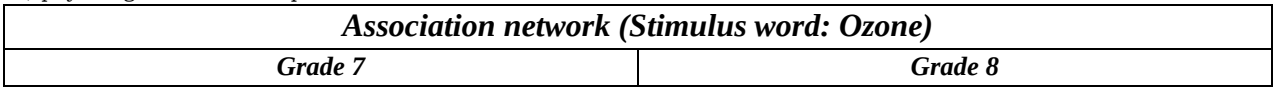


Figure 1: The most frequent associations obtained for the concept of 'sulphur-dioxide' (broken line: 20 – 39 % relative frequency; thin line: 40 – 59 % relative frequency; thick line: ≥ 60 % relative frequency).

The most common associations received for the stimulus word ozone can be seen in Figure 3. It is characteristic that most of the associations referring to ozone focus on it as a component of the ozone layer (ozone layer/layer/ozone shield/shield), they focus on its role (protection) and lesion (ozone hole/thinning) while other associations referring to the physical, physiological and other qualities of the matter do not appear. Labelling ozone with a formula only occurs in grades 10 and 12. Regarding relative frequency in the association network of the students in grades 11 and 12 we can only find associations below 40%, while we find them over 40% in other grades and what is more, there are associations over 60% in grade 9 (ozone layer/layer).



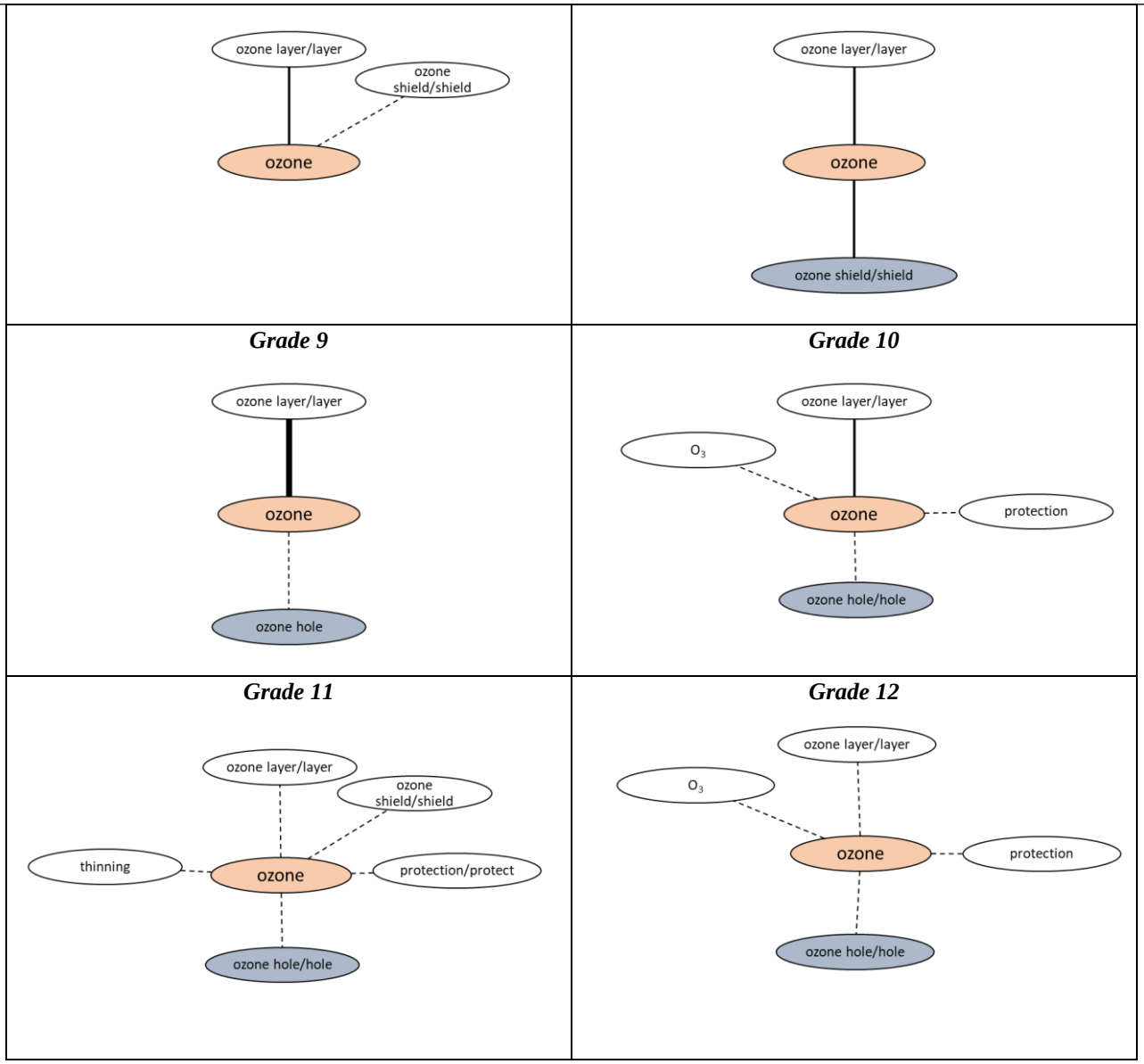
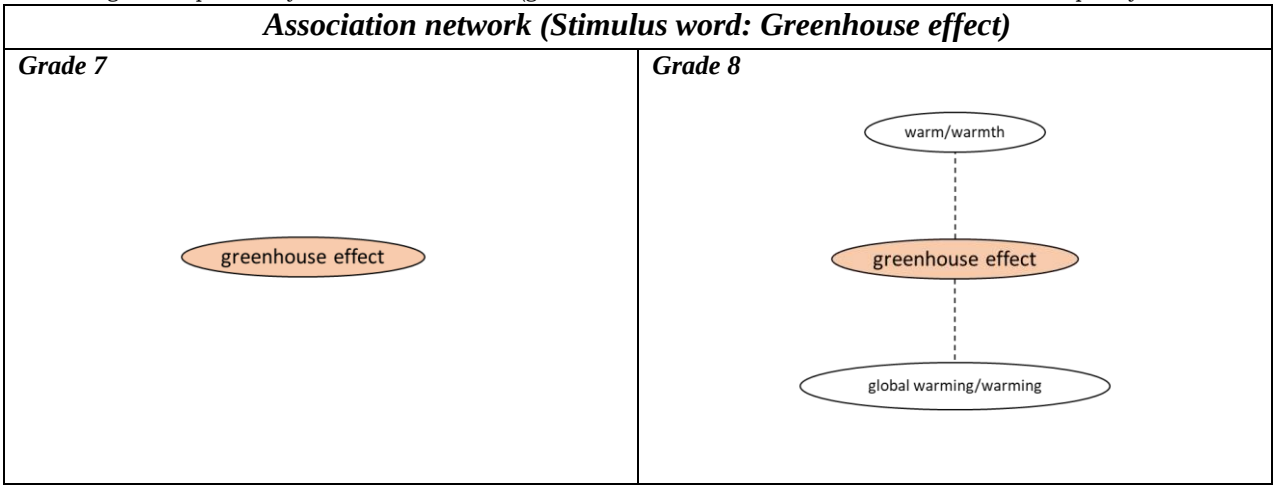


Figure 3: The most frequent associations obtained for the concept of 'ozone' (broken line: 20 – 39 % relative frequency; thin line: 40 – 59 % relative frequency; thick line: ≥ 60 % relative frequency)

Demonstrating the associations belonging to the concept of greenhouse effect we can see that very few associations (Figure 4). In most grades practically the same ones (global warming/warming, warmth) appear with mostly below 40% relative frequencies. In the case of grade 7 none of the associations reached 20% relative frequency.



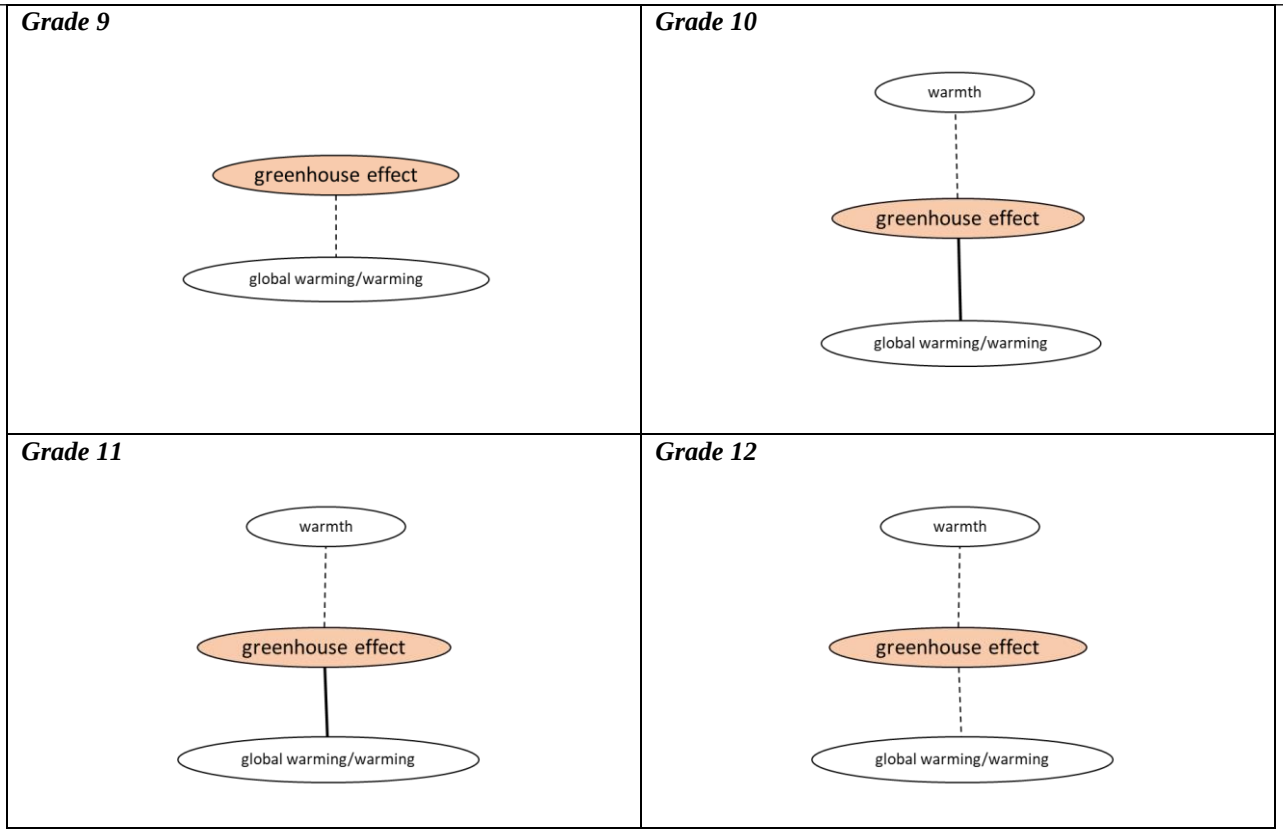
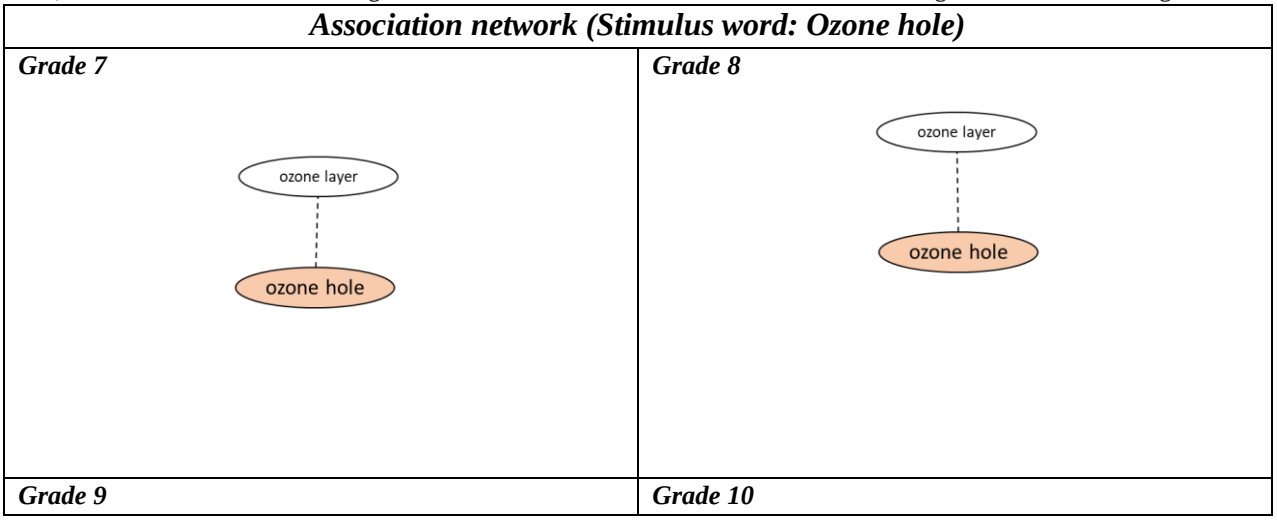


Figure 4: The most frequent associations given to the concept of 'greenhouse effect' (broken line: 20 – 39 % relative frequency; thin line: 40 – 59 % relative frequency; thick line: ≥ 60 % relative frequency).

There are also few associations, below 40% relative frequency, which belong to the stimulus word ozone hole in each grade (Figure 5). The association of ozone layer occur in grades 7-9, the association of ozone in grades 9-10 and the concept of UV-light/radiation in grades 11-12. The idea of global warming in grades 10 and 11 may refer to the common misconception that a portion of students believe that the ozone hole has something to do with global warming.



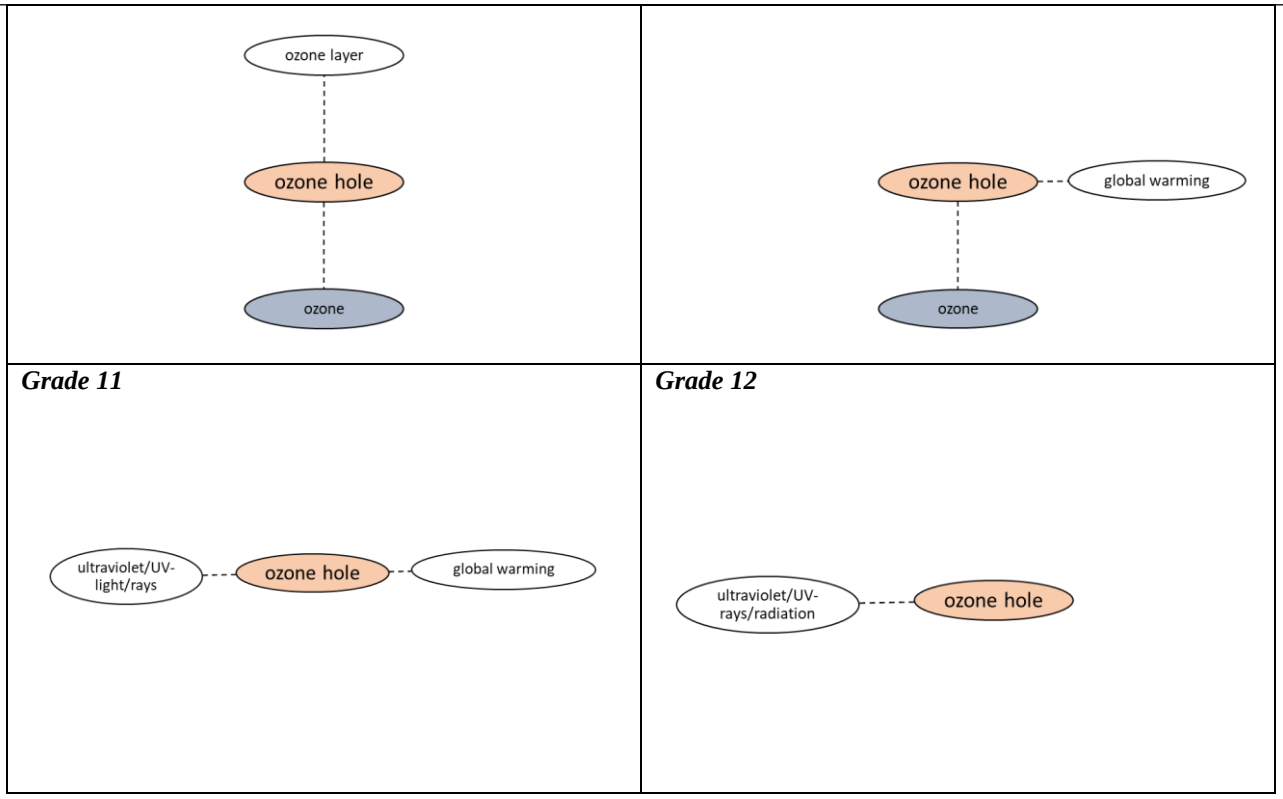
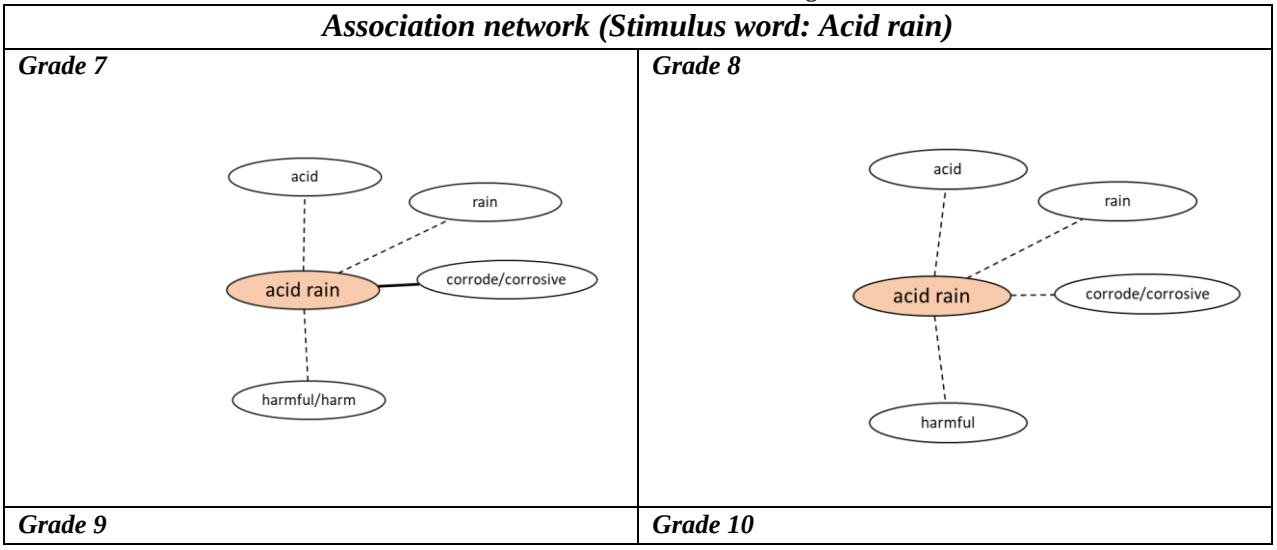


Figure 5: The most frequent associations given to the concept of 'ozone hole' (broken line: 20 – 39 % relative frequency; thin line: 40 – 59 % relative frequency; thick line: ≥ 60 % relative frequency).

Among the associations given to the stimulus word of acid rain the words 'acid' and 'rain' appear in several years (Figure 6), the reason of which might be phonetic. Another common association word are 'harmful' and 'corrosive'. Environmental pollution and destruction can be observed in grade 10, but it can be seen that beyond these general attributes, associations describing specific effects and those describing chemical aspects are missing.



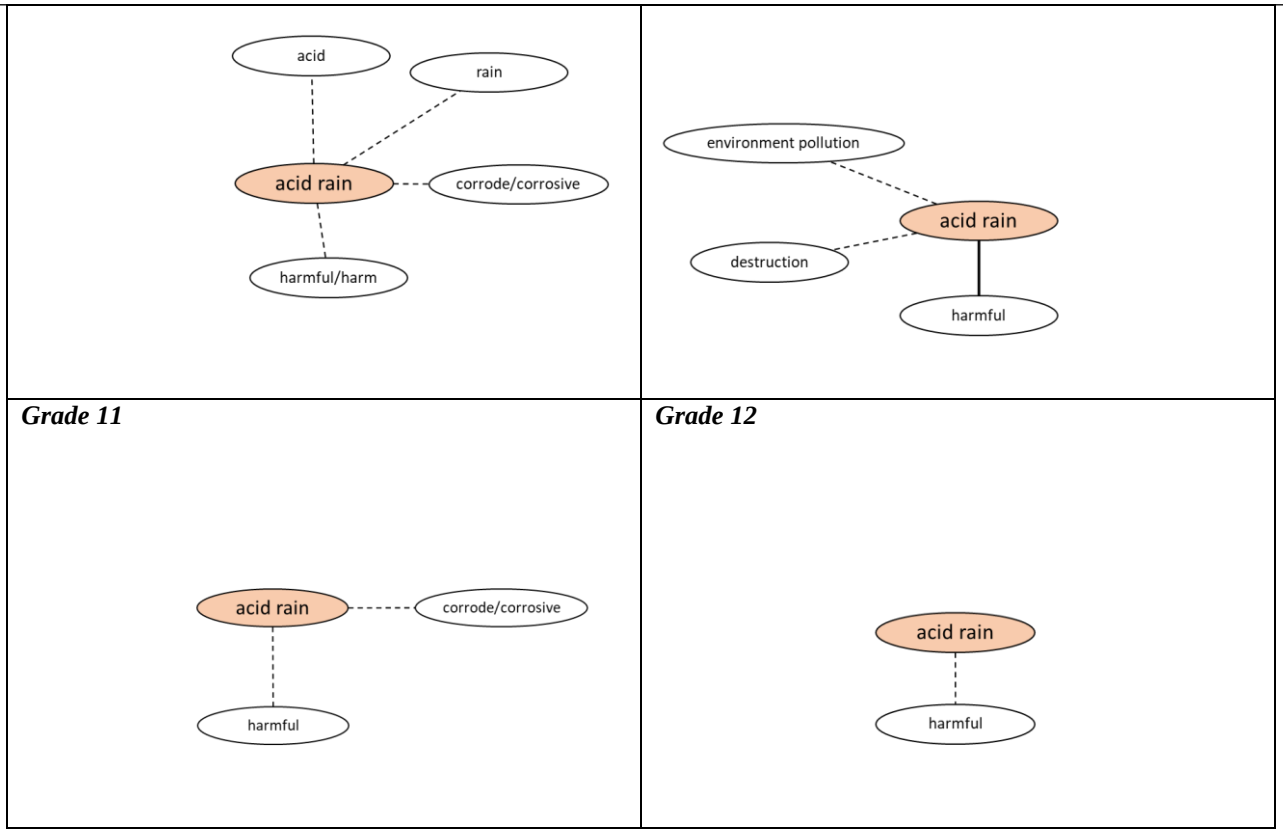


Figure 6: The most frequent associations given to the concept of 'acid rain' (broken line: 20 – 39 % relative frequency; thin line: 40 – 59 % relative frequency; thick line: ≥ 60 % relative frequency).

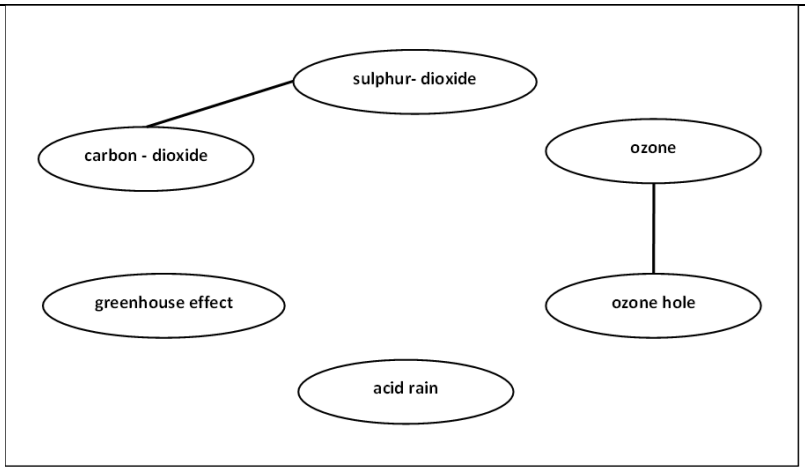
Based on the association networks we can conclude that the most associations belong to sulphur-dioxide and carbon-dioxide, while in the case of stimulus words greenhouse effect and ozone hole the networks are rather poor. It is characteristic of several stimulus words that relevant chemical, biological or other scientific concepts do not or hardly ever appear among the associations. The associational relation of the stimulus words greenhouse effect and ozone hole (global warming) may demonstrate bafflement of a serious conceptual comprehension in the case of grades 10 and 11. It is worth noting that the stimulus words are hardly one another's associations. The only case when this relation appears is the case of 'ozone-ozone hole' in almost every grade.

Conceptual networks characteristic of each individual grade

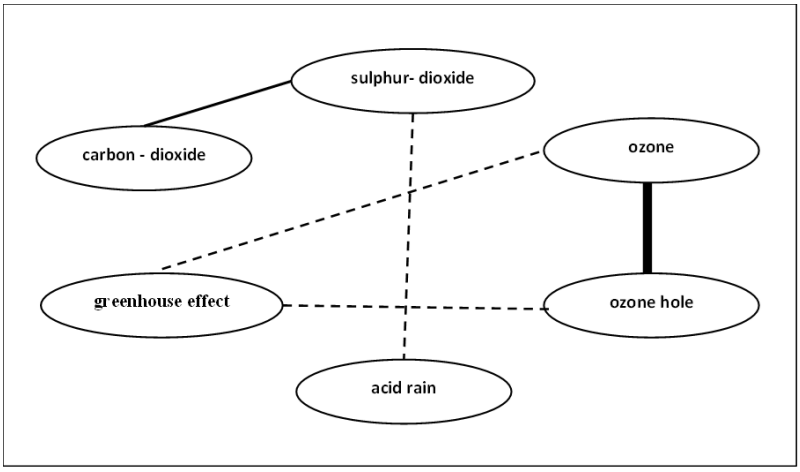
We calculated the individual relatedness coefficients for each student based on the number and the rank of the common associations of the stimulus word pairs (Garskof–Houston relatedness coefficient), and then we calculated the average for each grade. We designed the conceptual netwoks characteristic of each individual grade based on the average relatedness coefficients demonstrating the strength of the relation of the concept pairs. The strength of the relation in the conceptual networks is represented by the thickness of the lines connecting the concept pairs (Figure 7). The smallest demonstrated value is 0.05, concept pairs having a smaller relatedness coefficient (RC) than that are not represented in the conceptual network. We defined the following ranges: weak relation (RC 0.05–0.09), demonstrated with a broken line; relation of moderate strength (RC 0.10–0.19), demonstrated with a thin, continuous line; strong relation (RC ≥ 0.02), demonstrated with a thick, continuous line.

We can conclude based on the conceptual networks shown on Figure 7 that the relation between ozone and ozone hole appears and generally appears among the strongest relations in every school year. So does the relation of carbon-dioxide and sulphur-dioxide in almost each conceptual network with moderately large relatedness coefficient in general. In school year 7 there is a describable relation between only the above-mentioned concept pairs. The ozone – greenhouse effect and the sulphur-dioxide – acid rain concept pairs belong to the describable – generally weak – relations in every school year except for grade 7. However, the latter concept pair has strong relations in school year 12. The relation between greenhouse effect and ozone hole starts to appear in school year 8, with a weak relation here and in grade 9 while in the other grades with a moderately strong relation. There are some concept pairs which only appear in the conceptual network of certain grades. Such are the concept pairs of ozone hole – acid rain in school year 10 and carbon-dioxide – ozone hole and greenhouse effect – acid rain in grade 12. We can see that 7th graders have the fewest describable relations and 12th graders have the most. The other school years show fairly similar conceptual networks with one or two relatedness differences.

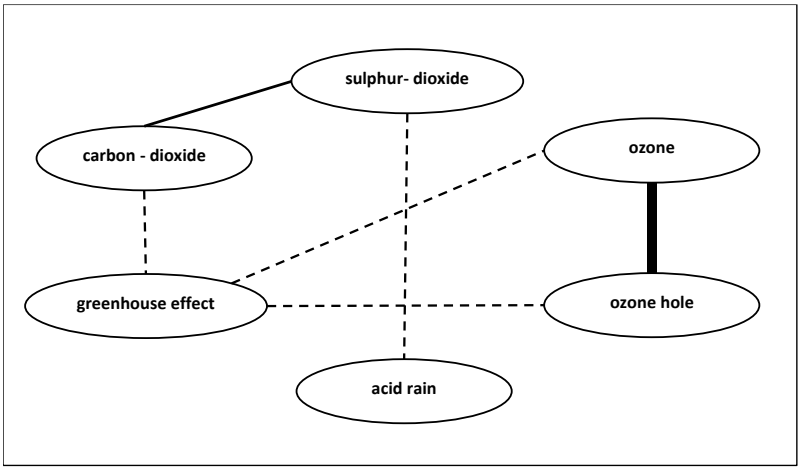
Conceptual networks
Grade 7



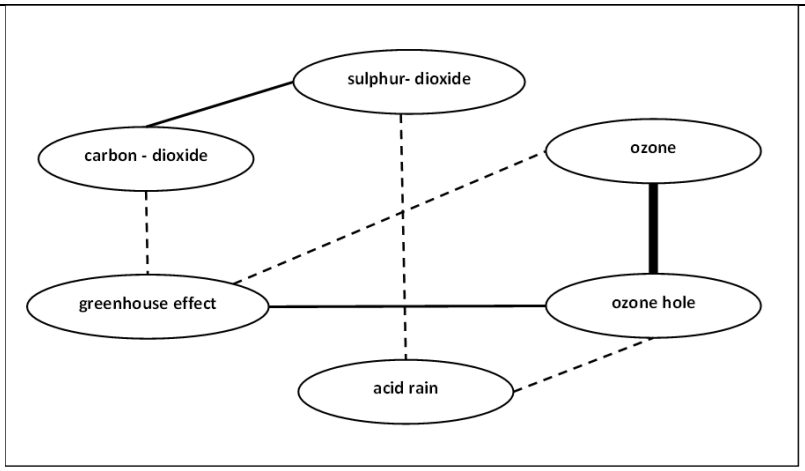
Grade 8



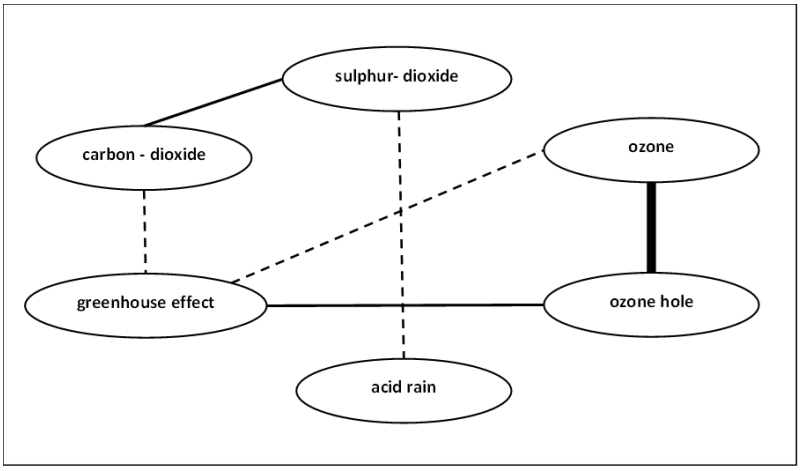
Grade 9



Grade 10



Grade 11



Grade 12

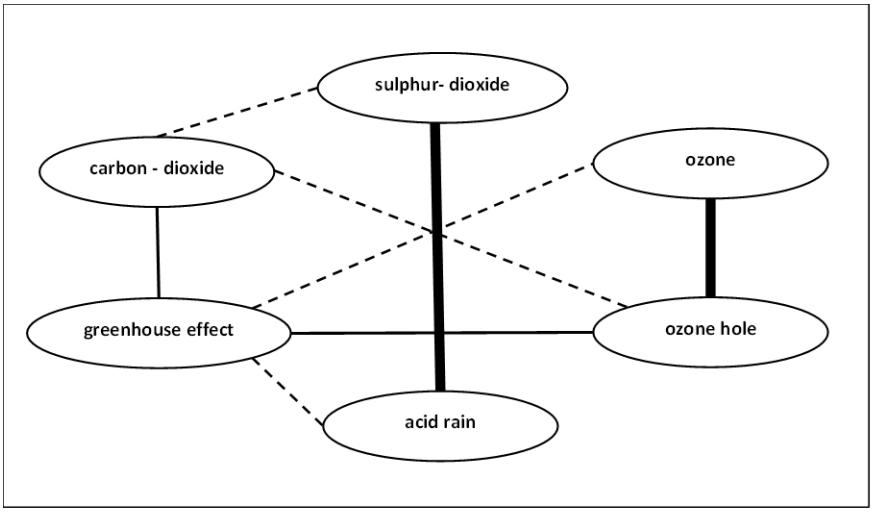


Figure 7: The conceptual networks between the stimulus words characteristic for the different graders (cut-off points: RC = 0.20; 0.10; 0.05).

5. Conclusion

We examined the conceptual structures of students in school years 7-12 related to air pollution by means of word associations. The association networks attached to each stimulus word generally become richer and richer up to school years 9-10, then stagnation or a decrease can be observed regarding the number and frequency of associations. At the same time in these conceptual networks, relations referring to misconceptions and errors of conceptional comprehension also occur (greenhouse effect – ozone hole, acid rain – ozone hole, acid rain – global warming) apart from the contextually correct relations, out of which the strongest one is the relation of ozone – ozone hole in almost every school year.

Acknowledgements

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