SECONDARY SCHOOL STUDENTS' PERCEPTION OF BIOCHEMISTRY CONCEPTS BY USING WORD ASSOCIATION TEST

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Abstract

A word association test was used to determine knowledge structures on biochemistry concepts of secondary school chemistry students, aged between 18-19 years. The basic biochemistry concepts related to the topic of Carbohydrates that take place in the International Baccalaurate Diploma Programme curriculum were determined as stimulus words: "Monosaccharides", "Glucose", "Cellular respiration", "Fructose", "Disaccharides", "Glycosidic bonds", "Polysaccharides", "Starch". Students were required to provide response words for each of the eight stimulus words within the pre-determined period of time. Analysis of data was done in order to find the stimulus words with the highest number of associations in students' knowledge structures and to calculate the relatedness coefficient between the stimulus words, in order to construct the relatedness networks that should model the students' knowledge structures. The results showed that students managed to relate most of the stimulus words with strong or medium strength links, however, "Cellular respiration" remained unconnected to other stimulus words in the students' knowledge structures.
Keywords: *biochemistry education, knowledge structures, secondary school students, word association test*

Introduction

It is well known that chemistry is a complex subject which deals with many abstract topics and concepts (Burrows & Reid Mooring, 2015) that, at the same time, represent fundamental ideas in chemistry courses. The students at both secondary and tertiary levels struggle with acquiring knowledge about the particulate nature of matter, chemical changes, chemical bonding, chemical equations and equilibrium, acids and bases (Treagust et al., 2000), energy in chemical reactions and the kinetics (Gegios et al., 2017), organic reaction types and mechanisms (Weber & Flynn, 2018).

In order to be understood, these concepts should be given a proper sense by the students. This could be achieved by making connections between the set of core concepts and fundamental ideas in order to develop a coherent and functional knowledge structure (Burrows & Reid Mooring, 2015). Knowledge structures are described as "mental structures of knowledge", while knowledge is organized around core concepts and big, fundamental ideas that guide the process of thinking (cited in Lopez et al., 2014).

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There are different ways to analyze the underlying concepts in students' knowledge structures, as well as connections among them. Here, the knowledge structure is modelled as an associative or relatedness network of nodes (i.e., concepts, terms, words) linked together (Nakiboglu, 2008). The strength of such links depends on the frequencies with which they appear, or how often they are used by the students. In the literature, concept maps, analogies, and word association tests are proposed to explore students' knowledge structure. Certainly, word association test is one of the oldest techniques that has been used in a variety of chemistry topics, such as atomic structure (Nakiboglu, 2008), physical and chemical changes (Nakiboglu, 2016), dissolution (Derman & Eilks, 2016). In biology education, Özarslan and Çetin (2018) applied a word association test to investigate secondary school students' knowledge structures about basic components of the living organisms, such as minerals, salts, vitamins, proteins, fats, and carbohydrates. However, according to our knowledge, there are no empirical studies on students' knowledge structures on carbohydrates as biomolecules and word association tests.

Research Problem and Research Focus

Biochemistry is an interdisciplinary, content-laden discipline (Vanderlelie, 2013) that applies chemistry to biological processes at both molecular and cellular levels (Salame et al., 2022). Even before learning about metabolic pathways (e.g., glycogenesis, beta-oxidation, urea and citric acid cycles), students encounter with complex names and structures of important biomolecules, with their vital role for leaving organisms to grow, sustain and reproduce, and the diversity of their functions. Taking into consideration the significance of these issues, biochemistry and biomolecules have been introduced in the chemistry syllabus within many secondary schools worldwide. Also, in some of the secondary school programs, the students have the possibility to choose this discipline as the optional one.

Research Aim and Research Questions

The aim of this study was to analyze secondary school students' knowledge structures and perceptions of "Carbohydrates" using a word association test (WAT). The WAT technique was chosen in order to look at the connectedness between some of the key biochemistry concepts within International Baccalaureate (IB) Diploma Programme students' knowledge structures. The following research questions were intended to be answered:

(1) How do IB students shape the concept of "Carbohydrates" in their minds?
(2) Which terms evoke the concept of "Carbohydrates" to them?
(3) On which level is the connectedness of "Carbohydrates" keywords within the IB chemistry students' knowledge structures?

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Research Methodology

General Background

The study was based on qualitative data collection, with the data analysis that combines both quantitative (i.e., analysis of frequencies) and qualitative data analysis procedures. The central research instrument was the word association test (WAT), and data gathered from WAT was subjected to content analysis in order to analyze how secondary school students perceive the key concepts of "Carbohydrates".

The processing of biochemistry contents and testing of International Baccalaureate (IB) Diploma Programme chemistry students with WAT were done at the beginning of the second semester of the 2022/2023 school year.

Sample

The secondary school students from the Gymnasium "Jovan Jovanović Zmaj", Novi Sad, Republic of Serbia participated in this study. The study sample consisted of the International Baccalaureate (IB) Diploma Program students who were taking their Chemistry course in English, which is not their native language, using an English textbook (Owen et al., 2014). The students were taught by one of the authors (T.R.).

The IB program is a rigorous pre-university two-year program dedicated to students aged 16 to 19. This study included only second-year students, and therefore, the research sample was small ($N = 8$, aged 18-19). It should be noted that regularly our second-year IB class consists of eleven students, however, on the day of testing with WAT, eight of them were present in chemistry classes. Two of the students have been taking chemistry course at a higher level (HL) and six of them at a standard level (SL). It should be highlighted that IB classrooms have a maximum of 25 students per class, as they should be equipped with modern and smart teaching aids and inquiry sources (https://www.modernschool.org/ib-curriculum/).

The IB program is different from the Serbian national program and national chemistry curriculum, not only in the contents learned but in the outcomes of learners' profiles. The IB students are encouraged to think critically and creatively, to develop and use conceptual understanding, to develop skills for inquiry, to design investigations and collect data, to apply practical approach, and to engage with issues of local and global significance (IB Diploma Programme, Chemistry Guide, 2016). Therefore, IB students are recognized worldwide as high standards achievers (Celestino & Marchetti, 2020).

Instrument and Procedures

The word association test (WAT) was used in this study as the data collection instrument for the teaching topic "Carbohydrates". IB Chemistry course syllabus has several components: core, additional higher level contents, options, and practical scheme of work. The core includes contents such as stoichiometric relationships, atomic structure, periodicity, chemical bonding and structure, etc., while options include materials, biochemistry, energy and medical chemistry (IB Diploma Programme, Chemistry Guide, 2016). At the beginning of the second year of the Diploma Programme, the IB students

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selected Option B – Biochemistry which includes six teaching topics common for both SL and HL students (15 teaching hours), and four additional teaching topics for HL students only (additional 10 teaching hours) (see Table 1).

Table 1
IB Chemistry Cours Syllabus for the Option B – Biochemistry

No.	Teaching contents	Level
B.1	Introduction to biochemistry	SL/HL
B.2	Proteins and enzymes	SL/HL
B.3	Lipides	SL/HL
B.4	Carbohydrates	SL/HL
B.5	Vitamins	SL/HL
B.6	Biochemistry and the environment	SL/HL
B.7	Proteins and enzymes (inhibitors, amino acids, and proteins as buffers in solutions, UV-VIS spectroscopy)	HL
B.8	Nucleic acids	HL
B.9	Biological pigments	HL
B.10	Stereochemistry in biomolecules	HL

The WAT was applied after instruction on "Carbohydrates" in January 2023. Before starting the application, the students were informed about the purpose and structure of WAT. All students agreed to voluntarily participate in the research. A booklet with eight stimulus words (i.e., keywords) was provided to the IB students. Each stimulus word was noted on a separate page, according to the recommendations by Derman and Eilks (2016) and Nakiboglu (2008) with the aim to prevent a chain effect that has been explained as a distraction from the stimulus word (Nakiboglu, 2008). The stimulus words were presented in the following order: "*Monosaccharides*", "*Glucose*", "*Cellular respiration*", "*Fructose*", "*Disaccharides*", "*Glycosidic bond*", "*Polysaccharides*", "*Starch*". The concepts that have been included in WAT were terms noted in "IB points to understand the topic" and the terms that were bolded in the textbook.

After receiving the booklet, the students were asked to write the response words to each of the eight stimulus words. They were encouraged to write as many response words as they could in the limited time period of 60 seconds. There were blanks after each stimulus word on the paper left for the students to respond (Figure 1). The free WAT technique with a pre-specific period of time was used, in which the students had to write concepts (i.e., response words) which were brought to their mind by the stimulus words and to decide which response words were the most important in order to be related with the stimulus word (Tsai & Huang, 2002). Also, at the end of each page in the booklet, there were lines provided to students to write sentences related to the stimulus word by using written response words (Figure 1). The students were given an additional 60 seconds for writing the sentence(s) for each stimulus word. However, the analysis of these sentences is not part of this report.

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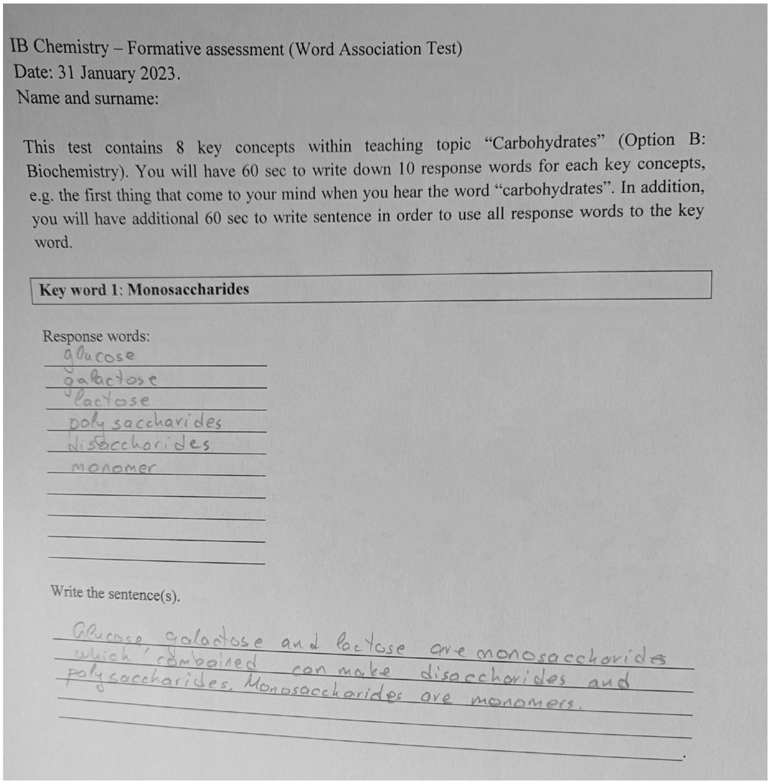
Figure 1

The First Page of the WAT Booklet with the HL Student' Responses



IB Chemistry – Formative assessment (Word Association Test)
Date: 31 January 2023.
Name and surname:

This test contains 8 key concepts within teaching topic "Carbohydrates" (Option B: Biochemistry). You will have 60 sec to write down 10 response words for each key concepts, e.g. the first thing that come to your mind when you hear the word "carbohydrates". In addition, you will have additional 60 sec to write sentence in order to use all response words to the key word.

Key word 1: Monosaccharides

Response words:
glucose
galactose
lactose
polysaccharides
disacchorides
monomer

Write the sentence(s).

Glucose, galactose and lactose are monosacchorides which, combined can make disacchorides and polysaccharides. Monosaccharides are monomers.

Data Analysis

Data obtained through WAT were analyzed in several stages. Firstly, the response words for each stimulus word and each student were examined. The list of response words was formed, and the number of different response words for each stimulus word was counted. The list of response words was used to create a frequency table.

In the next stage, Garskoff and Houston's relatedness coefficient, RC, was calculated for each pair of stimulus words. The relatedness coefficient (RC) between the stimulus words has been calculated using the formula and the mathematic procedure presented in the paper by Bahar et al. (1999):

$$RC = \frac{\bar{\mathrm{A}} \times \bar{\mathrm{B}}}{(\mathrm{A} \times \mathrm{B}) - 1}$$

However, it should be highlighted that the modification was done in the mathematical procedure in comparison with the original source. In the paper by Bahar et al. (1999), in the formula, $\bar{A}$ represents the rank order of occurrence of terms under stimulus word A that are shared in common with stimulus word B, while $\bar{B}$ represents the rank order of occurrence of terms under stimulus word B that are shared in common with stimulus word A. In the procedure followed in this study, $\bar{A}$ represents the real frequencies of the response words that are shared in common with stimulus word B, while $\bar{B}$ represents the real frequencies of the response words that are shared in common with stimulus word A. In the original version "A x B" represents the sum of the products of the rank order of the terms noted within the stimulus word A multiplied by the rank order of terms noted within the stimulus word B (Bahar et al., 1999), and in the following procedure, "A x B" represents the sum of products of the frequencies of the response words noted within stimulus word A multiplied with sum of the products of the frequencies of the response words noted within stimulus word B.

At the final stage, students' knowledge structure was visualized by mapping technique – relatedness networks, which were drawn by using calculated values of RC.

Research Results

At the beginning of the data analysis, the total number of different response words was counted for each stimulus word. For the eight stimulus words, a total number of 102 response words was found. The number of different response words varied within different stimulus words. The stimulus words for which the IB students wrote the highest number of different response words were: "*Monosaccharides*" with the frequency f = 28, and "*Glucose*" (f = 28), and after that "*Starch*" (f = 27). On the other hand, for the stimulus words "*Polysaccharides*" (f = 16), "*Glycosidic bond*" (f = 18) and "*Fructose*" (f = 20) there were significantly lower numbers of diverse response words provided by the IB students.

Afterwards, a frequency table was formed including eight stimulus words (noted in columns in Table 2 as SW1 to SW8) and response words (noted in rows in Table 2), showing the frequency of response words associated with the stimulus words. The frequency table has been arranged by the alphabetical order of response words and Table 2 shows only one, a small part of the complete frequency table because of the numerous response words. It should be highlighted that some response words were actually the repeated stimulus words. For example, "*Disaccharides*" appeared 4 times as the response word for the SW1 ("*Monosaccharides*"), 4 times for SW4 ("*Fructose*"), 5 times for SW6 ("*Glycosidic bond*"), 3 times for SW7 ("*Polysaccharides*"), and 2 times as the response word for the SW8 ("*Starch*"). Therefore, it was found that some of the response words like "*Disaccharides*" appeared within several stimulus words, while for example, the response words like "*Aerobic*" (see Table 2) or "*Iodine test*" appeared only once as a response word for the stimulus word "*Cellular respiration*" and "*Starch*" respectively.

https://doi.org/10.33225/BalticSTE/2023.190

Table 2
A Frequency Table with WAT Frequency Values

Response words	Stimulus words (Frequency of response words)							
	SW1	*SW2*	*SW3*	*SW4*	*SW5*	*SW6*	*SW7*	*SW8*
Aerobic	-	-	1	-	-	-	-	-
Acid	-	-	-	-	-	1	-	-
Air	-	-	1	-	-	-	-	-
Alcohol	-	-	-	1	-	-	-	-
Allergic	-	1	-	-	-	-	-	-
Alpha helix	1	1	-	-	-	-	-	-
Alveoli	-	-	1	-	-	-	-	-
Amino group	1	-	-	-	-	-	-	-
Amylopectin	-	-	-	-	-	-	-	1
Amylose	-	-	-	-	-	-	-	2
Anaerobic	-	-	2	-	-	-	-	-
Anomeric hydroxyl group	1	-	-	-	1	-	-	-
Apple	-	-	-	1	-	-	-	-
ATP	-	-	4	-	-	-	-	-
Base	-	-	-	-	-	1	-	-
Beta pleated sheet	1	1	-	-	-	-	-	-
Between	-	-	-	-	-	1	-	-
Biose	-	-	-	-	1	-	-	-

Note: SW1: *Monosaccharides*; SW2: *Glucose; SW3: Cellular respiration; SW4: Fructose; SW5: Disaccharides; SW6: Glycosidic bonds;* SW7: *Polysaccharides; SW8: Starch.*

In addition, it was important to calculate and interpret the relatedness coefficient, RC, for each pair of the stimulus words and the results are presented in Table 3. An example of the calculation is presented below the text, observing the RC between the SW1 (“*Monosaccharides*”) and SW2 (“*Glucose*”). The calculated value shows strong relatedness between these two stimulus words (interpreted according to Nakiboglu, 2008).

$$RC = \frac{\bar{\mathrm{A}} \times \bar{\mathrm{B}}}{(\mathrm{A} \times \mathrm{B}) - 1}$$

$$= \frac{(1,1,1,2,3,2,1,2,4,2,2,5)\mathrm{x}\ (1,1,1,1,2,1,3,1,1,1,1,6)}{(5,5,4,4,3,3,3,2,2,2,2,2,2,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1)\mathrm{x}(6,6,3,2,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1,1) - 1}$$

$$= 0.487$$

Table 3
Relatedness Coefficient, RC, Between the Stimulus Words

Stimulus words	Relatedness coefficient, RC (0 – 1)							
	SW1	*SW2*	*SW3*	*SW4*	*SW5*	*SW6*	*SW7*	*SW8*
SW1	-	0.487	0.096	0.375	0.467	0.355	0.265	0.341
SW2	0.487	-	0.078	0.659	0.750	0.288	0.677	0.292
SW3	0.096	0.078	-	0.076	0.047	0.110	0.033	0.141
SW4	0.375	0.659	0.076	-	0.516	0.487	0.537	0.333
SW5	0.467	0.750	0.047	0.516	-	0.192	0.602	0.263
SW6	0.355	0.288	0.110	0.487	0.192	-	0.481	0.400
SW7	0.265	0.677	0.033	0.537	0.602	0.481	-	0.366
SW8	0.341	0.292	0.141	0.333	0.263	0.400	0.366	-

It can be seen from Table 3 that RC values ranged from 0.033 to 0.750. It was clearly perceived that RCs for the SW3 („*Cellular respiration*“) were really low for each pairing of SW3 with the other stimulus words. Namely, any of the calculated RC values did not exceed the required value of 0.200 (i.e. the lowest acceptable value of RC).

According to Nakiboglu (2008), RC≥0.350 was chosen as the starting cut-off point for drawing relatedness networks between stimulus words (Figure 2). The next cut-off point was done for the 0.350>RC≥0.300 (Figure 3), and the last one for the 0.300>RC≥0.250 (Figure 4). It should be noted that in the original paper (Nakiboglu, 2008) the last cut-off point was done for the 0.250>RC≥0.200, however, in the present study, there were no RC values in this range (see Table 3). The relatedness networks are presented in Figure 2, Figure 3 and Figure 4.

The strongest interconnectedness of stimulus words is presented in Figure 2. There were 14 RC values greater than 0.350 and such strong association was formed between (1) "*Monosaccharides*" – "*Glucose*", (2) "*Monosaccharides*" – "*Fructose*", (3) "*Monosaccharides*" – "*Disaccharides*", (4) "*Monosaccharides*" – "*Glycosidic bond*", (5) "*Glucose*" – "*Fructose*", (6) "*Glucose*" – "*Disaccharides*", (7) "*Glucose*" – "*Polysaccharides*", (8) "*Fructose*" – "*Disaccharides*", (9) "*Fructose*" – "*Polysaccharides*", (10) "*Fructose*" – "*Glycosidic bond*", (11) "*Glycosidic bond*" – "*Polysaccharides*", (12) "*Glycosidic bond*" – "*Starch*", (13) "*Polysaccharides*" – "*Starch*", and (14) "*Disaccharides*" – "*Polysaccharides*". It was interesting to note that even though IB students were not able to provide a higher number of diverse response words for the stimulus words "*Polysaccharides*" (*f*=16) and "*Fructose*" (*f*=20), these stimulus words achieved the strongest associations with other five stimulus words in students' knowledge structures.

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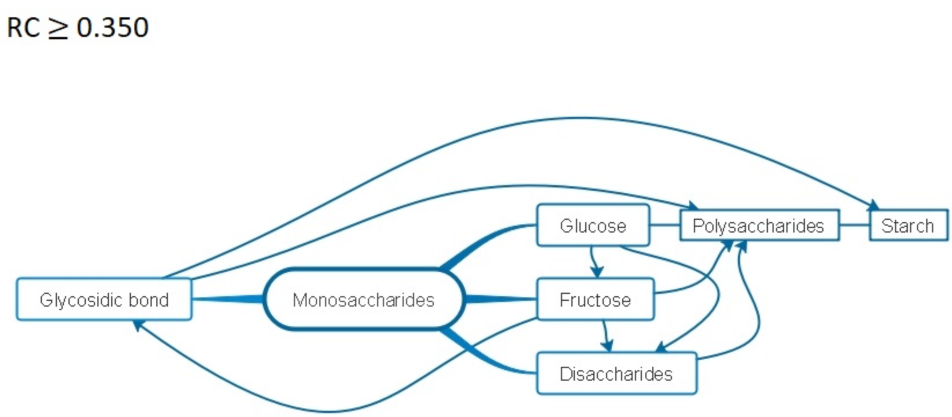
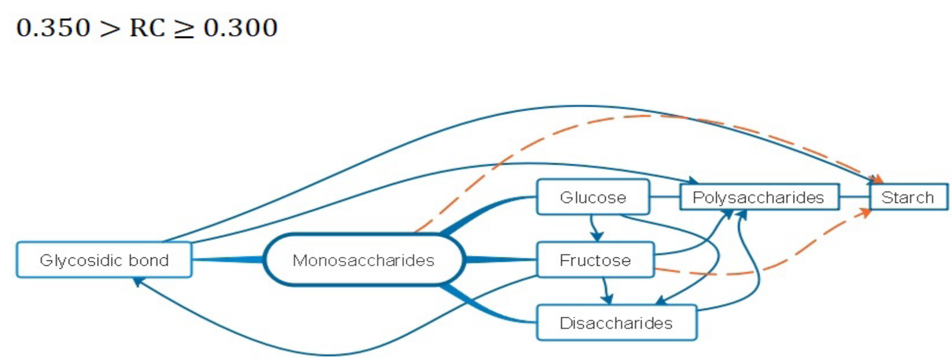
Figure 2
The Relatedness Networks between Stimulus Words for the RC≥0.350



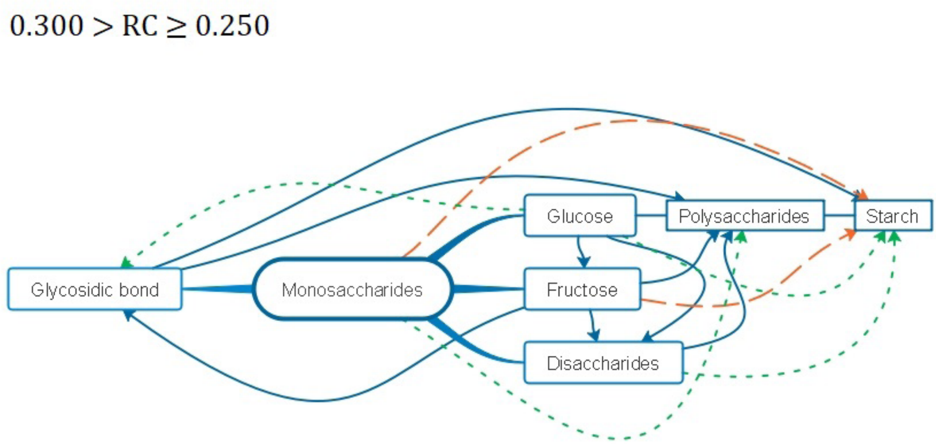
Further lowering of RC to 0.300 showed the other two connections of medium strength between the following stimulus words: (1) "*Monosaccharides*" – "*Starch*" and (2) "*Fructose*" – "*Starch*" (Figure 3, dashed, orange lines). Both connections were recorded for the stimulus word "*Starch*".

Figure 3
The Relatedness Networks between Stimulus Words for the 0.350>RC≥0.300



Additional lowering of RC to 0.250 provided three connections of weak strength. Looking at Figure 4 (dashed, green lines), these connections are formed between the stimulus words (1) "*Glucose*" – "*Glycosidic bond*", (2) "*Monosaccharides*" – "*Polysaccharides*", and (3) "*Disaccharides*" – "*Starch*".

Figure 4
The Relatedness Networks between Stimulus Words for the 0.300>RC≥0.250



Discussion

As the aim of this study was to determine the IB students' knowledge structure in the biochemistry discipline within the teaching topic "Carbohydrates", the frequency map was formed in order to reveal the richness of the response words for each of the eight stimulus words. If the number of different response words is considered a direct and significant indication of interlinks in students' minds (Nakiboglu, 2008), the assumption could be made that "*Monosaccharides*" and "*Glucose*" are better structured in students' knowledge structures than the other stimulus words. Even though the literature sources indicate that students' ability to provide a high number of different response words to the key or stimulus word is a good indicator of students' understanding (Atabek-Yigit, 2016), in our study, this was not accepted as a hundred per cent correct. Namely, the stimulus words for which the students provided a lower number of diverse response words (SW7 – "*Polysaccharides*" and SW4 – "*Fructose*"), showed the highest commonality with the other stimulus words in the students' knowledge structures. These results were found in the analysis of the relatedness coefficient and presented within the relatedness networks. Anderson and Schönborn (2008) noted that the biochemistry discipline passes through a constant increase in new knowledge, but primarily, it is crucial that students develop core conceptual knowledge of this specific discipline.

Taking into account the relatedness networks that show students' knowledge structures about teaching topic "Carbohydrates", it should be highlighted that there were no "isolated islands" or independent associations between the stimulus words (Nakiboglu, 2008), as even at the level of the strongest interconnectedness, each of the seven stimuli words is connected with two or more other stimulus words. According to Bahar et al. (1999) the meaning of the concept (i.e., stimulus word) is enriched as more connections are formed with other key concepts from the observed discipline. However, the stimulus word "*Cellular respiration*" (SW3) remained totally unconnected with other stimulus words from the teaching topic "*Carbohydrates*" as this stimulus word did not appear on any of the three relatedness networks. It could be said that stimulus word "*Cellular respiration*" remained static, non-interactive and limited in light of external connections (according to Derman & Eilks, 2016) with the other key words from the teaching topic "*Carbohydrates*".

Conclusions and Implications

In this study, WAT was successfully used as a tool in order to reveal the organization of key concepts in IB students' knowledge structures about "Carbohydrates". It must be emphasized that WAT was applied immediately after the instruction on Biochemistry contents and the IB students were not prepared for WAT in the way as they did for the real exams. Therefore, presented results show the "row state" before the deeper learning happened. In this point, it would be valuable to repeat the WAT now, after the exam on Biochemistry contents and to compare the results. Perhaps, we might expect better results from the repeated testing regarding the stimulus word that was totally isolated from the others (SW3 – "*Cellular respiration*"). Additionally, as each student was required to write sentences in order to use the response words for each of eight stimulus words, these sentences should be analyzed and put into categories as irrelevant (off topic sentences), misconceptions and correct scientific knowledge.

At the end, not many authors choose International Baccalaureate Diploma Programme students as a study sample for the empirical research. Certainly, in the literature, there are topics like preparing students for the IB program, or some results on the questionnaire why students choose to do the IB, or the analysis of learning outcome of national and IB program. Therefore, presented research results provide some new insights into IB students profiles and their patterns to corelate concepts in their minds.

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Declaration of Interest

The authors declare no competing interest.

References

Anderson, T. R., & Schönborn, K. J. (2008). Bridging the educational research-teaching practice gap: Conceptual understanding, part 1: The multifaceted nature of expert knowledge. *Biochemistry and Molecular Biology Education*, *36*(4), 309–15. https://doi.org/10.1002/bmb.20209

Atabek-Yigit, E. (2016). Investigating cognitive structures in some basic chemistry concepts via word association test. *Elementary Education Online*, *15*(4), 1385–1398. http://dx.doi.org/10.17051/io.2016.12031

Bahar, M., Johnstone, A. H., & Sutcliffe, R. G. (1999). Investigation of students' cognitive structure in elementary genetics through word association tests. *Journal of Biological Education*, *33*(3), 134–141. http://dx.doi.org/10.1080/00219266.1999.9655653

Burrows, N. L., & Reid Mooring, S. (2015). Using concept mapping to uncover students' knowledge structures of chemical bonding concepts. *Chemistry Education Research and Practice*, *16*(1), 53–66. https://doi.org/10.1039/C4RP00180J

Celestino, T., & Marchetti, F. (2020). Surveying Italian and International Baccalaureate teachers to compare their opinions on system concept and interdisciplinary approaches in chemistry education. *Journal of Chemical Education*, *97*(10), 3575–3587. https://dx.doi.org/10.1021/acs.jchemed.9b00293

Derman, A., & Eilks, I. (2016). Using a word association test for the assessment of high school students' cognitive structures on dissolution. *Chemistry Education Research and Practice*, *17*(4), 902–913. https://doi.org/10.1039/C6RP00084C

Diploma Programme Chemistry Guide (2016). *The International Baccalaureate Organization*. Wales, United Kingdom.

Gegios, T., Salta, K., & Koinis, S. (2017). Investigating high-school chemical kinetics: The Greek chemistry textbook and students' difficulties. *Chemistry Education Research and Practice*, *18*(1), 151–168. https://doi.org/10.1039/C6RP00192K

Lopez, E. J., Shavelson, R. J., Nandagopal, K., Szu, E., & Penn, J. (2014). Ethnically diverse students' knowledge structures in first-semester organic chemistry. *Journal of Research in Science Teaching*, *51*(6), 741–758. https://doi.org/10.1002/tea.21160

Modern School. (2023, April 15). International Baccalaureate. https://www.modernschool.org/ib-curriculum/

Nakiboglu, C. (2008). Using word associations for assessing non major science students' knowledge structure before and after general chemistry instruction: The case of atomic structure. *Chemistry Education Research and Practice*, *9*(4), 309–322. https://doi.org/10.1039/B818466F

Nakiboglu, C. (2016). Probing high school students' cognitive structure about physical and chemical changes through word association test. *The Eurasia Proceedings of Educational & Social Sciences*, *4*, 486–489.

Owen, S., Ahmed, C., Martin, C., & Woodward, R. (2014). *Chemistry for the IB Diploma*. Cambridge University Press.

Özarslan, M., & Çetin, G. (2018). Biology students' cognitive structures about basic components of living organisms. *Science Education International*, *29*(2), 62–74. https://doi.org/10.33828/sei.v29.i2.1

Salame, I. I., Abid, M., & Simms, S. (2022). Examining some of the challenges that students face in learning about metabolic pathways in a traditional biochemistry course. *International Journal of Instruction*, *15*(4), 277–292.

Treagust, D., Duit, R., & Nieswandt, M. (2000). Sources of students' difficulties in learning Chemistry. *Educación Química*, *11*(2), 228–235. https://doi.org/10.22201/fq.18708404e.2000.2.66458

Tsai, C. C., & Huang, C. M. (2002). Exploring students' cognitive structures in learning science: A review of relevant methods. *Journal of Biological Education*, *36*(4), 163−169. https://doi.org/10.1080/00219266.2002.9655827

Vanderlelie, J. J. (2013). Improving the student experience of learning and teaching in second year biochemistry: Assessment to foster a creative application of biochemical concepts. *International Journal of Innovation in Science and Mathematics Education*, *21*(4), 46−57.

Webber, D. M., & Flynn, A. B. (2018). How are students solving familiar and unfamiliar organic chemistry mechanism questions in a new curriculum? *Journal of Chemical Education*, *95*(9), 1451−1467. https://doi.org/10.1021/acs.jchemed.8b00158

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