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MNEMONIC METHODS AS A SOPHISTICATED TOOL IN LEARNING THE SCIENCE SUBJECTS FROM POLISH PUPILS POINT OF VIEW

1. Introduction

The word “mnemonic” derives from the Greek goddess of memory - Mnemosyne, and means “memory enhancing”. Mnemonic (“nee-moh-nick”) techniques, also called mnemonic strategies, mnemonic devices or mnemonics, are systematic procedures designed to improve our memory¹. Hence, mnemonics strategies ought to be understood as systematic procedures for intensification a memory. The main idea of mnemonic strategies is application in developing better ways to encode (take in) information, so that it will be much easier to retrieve (remember)². Therefore, mnemonic devices can be attended as learning strategies which can often enhance the learning and later recall of information^{3,4}. The main task in developing mnemonic strategies is to find a way to connect new information to information students have already locked in long-term memory. If pupils or students make an enough strong connection, the memory will last a very long time, because the mnemonic strategy had carefully linked it to things that will be very familiar according to these procedures can be extraordinarily effective². Moreover, the mnemonic strategies can be incorporated for the elements that require recall, what is both advantage and disadvantage of this method. These methods are also useful way of improving

¹ J.Guthrie, *Encyclopedia of Education*, Macmillan Reference 2002, p. 1669-1672.

² M. T. S., Mastropieri *Enhancing School Success with Mnemonic Strategies*, Intervention in school and clinic 1998, 33, p. 201-209.

³ F.Bellezza, *Mnemonic Devices Classification, Characteristics, and Criteria*, Review of Educational Research, Review of Educational Research 1981, 51, p. 247-275.

⁴ M.Mastropieri, T.Scruggs, *Text Versus Hands-On Science Curriculum Implications for Students with Disabilities*, Remedial and Special Education 1994, 15, p. 72-85.

memory in students, who exhibit difficulty with remembering things. Hence, the mnemonic devices do not represent an educational panacea, but can be an important component in improving memory and learning or teaching process^{5,6}.

2. Methods and idea of studies

In according to gather information about the examples of mnemonics devices used by pupils, the appropriate questionnaires about general information were prepared – Appendix 1. We construct questionnaire according to information about participants (gender, age, race/ethnicity) and also information related to the examples of mnemonic methods. It must be emphasized that in this article we only focused on last question – “Give the any example/s being with the mnemonics which most often you use or which best you remember” (question 8. in Appendix 1).

Before the accession to the questionnaire about mnemonics method, all students were informed that their answers were anonymous and results will be published in scientific article. All of the participants filled questionnaires individually, at school after lessons having the appropriate time on their own answers (approx. the one lesson hour), however they could not use any sources (e.g. books, phones, internet, own notes etc.) and they could not communicate with each other. The research was made in period of September – December in 2014.

3. Participants

Are students of Upper Secondary Schools in Poland apply mnemonic devices when they are learning science subjects? In research took part two public Upper Secondary Schools in Warsaw from full-day state-funded class-rooms. Four hundred and seventy nine ($N = 479$ students), aged: 15 – 19 years ($M_{\text{age}} = 17.48$ years, $SD = 1.1$) participated in these studies. Differences in the level of participation are the same due to the fact that in all classes, the same curriculum (program) is applied. We had an approximately number of males and females in each class. For this experiment, in both schools we investigated two subgroups of all examined classes – each class had been divided into two groups. First group (a control group) had lessons in classical way; the second group (experimental group) had lessons with application the chemical mnemonics devices. The participants were given ball pens and pencils as a compensation for their involvement. The **Table 1.** and **Table 2.** presents all participants characteristics by conditions.

⁵ M.Levin, J.Levin, *Scientific mnemonics: Methods for maximizing more than memory*, Am Educ Res J.1990, 27, p. 301-321.

⁶ F.Bellezza, *Mnemonic Methods to Enhance Storage and Retrieval*, Memory - Handbook Perception and Cognition; Carterette, E. C. Friedman, M. P. Eds.; Academic Press: Los Angeles, California, 1996.

Table 1.

Students characteristics, by conditions in School 1. (n = 241).

Level of education	1 st classes n = 77			2 nd classes n = 81			3 rd classes n = 83		
	(%)	n	Missing ^a	(%)	n	Missing ^a	(%)	n	Missing ^a
<i>Gender</i>		76	1		81	0		83	0
Male	48.7			51			53		
Female	51.3			49			47		
<i>Race/ethnicity</i>		75	2		83	1		79	4
European	90.4			98.8			89.3		
Asian	5.5			0			4.0		
Other ^b	4.1			1.2			6.7		
<i>Student's Age (in years)</i>		74	0		84	0		82	1
15	1.3			0			0		
16	93.2			1.2			0		
17	5.5			94.0			1.2		
18	0			4.8			97.6		
19	0			0			1.2		

^a due to the fact that participant did not mark (empty answer)

^b e.g. national minorities (Jew, Gipsy)

Table 2.

Students characteristics, by conditions in School 2. (n = 238).

Level of education	1 st classes n = 81			2 nd classes n = 79			3 rd classes n = 78		
	(%)	n	Missing ^a	(%)	n	Missing ^a	(%)	n	Missing ^a
<i>Gender</i>		81	0		78	1		77	1
Male	51.8			43,6			53.2		
Female	48.2			56.4			46.8		
<i>Race/ethnicity</i>		78	3		79	0		76	2
European	100			98.8			92.1		
Asian	0			0.0			1.3		
Other ^b	0			1.2			6.6		
<i>Student's Age (in years)</i>		80	1		76	3		78	0
15	2.5			0			0		
16	93.75			5.5			0		
17	3.75			94.5			2.5		
18	0			0			92.4		
19	0			0			5.1		

^a due to the fact that participant did not mark (empty answer)

^b e.g. national minorities (Jew, Gipsy)

4. Results and discussion

4.1 Mnemonic methods in chemistry teaching and learning

Mnemonic devices in chemistry has been noted more than 50 years ago, when⁷ published short (but detailed) review on the topic of mnemonics in chemistry education. Mnemonics have also been regarded as a useful aid in the study of chemistry. Flipper and Morris⁸ state that learning chemistry, in addition to learning by inference, also requires the foundations to which the student becomes familiar only through their memorization. Of these foundations the authors mention the names of the elements, the gas laws and the generalisations regarding the solubility of inorganic salts. Aspect of the existence of the content to be remembered is also stressed by Bermingham⁹ who gives a set of mnemonics applicable in chemistry. Chemistry teaching was also, among others, the subject of interest of Masachika Nakane, the creator of Yodai mnemonic methods. This method is based on the assumption, that the main goal of students, trying to remember scientific foundations through mnemonics, is ascribed to organization and the process of problem solving. Yodai method was applied to organic and inorganic chemistry teaching¹⁰. The results of the study performed by Mastropieri et al.¹¹ are setting the solid foundation for the use of mnemonic devices in chemistry classes, where students tutored with mnemonic techniques outperformed students taught with a classical approach.

Mobile Reference¹² serves with several illustrations of mnemonics designed in order to know key terms in redox reaction off pat. The examples include expression such as: *OIL-RIG (Oxidation Is Loss, Reduction Is Gain [of electrons]); LEO the lion says GER (Losing Electrons is Oxidation, Gaining Electrons is Reduction); Visualize OXen going up a mountain (just as oxidation number of an OXidation goes up) and RED blood flowing down the mountain (just as the oxidation number of a REDuction goes down); "EOH" remind you to include an electron and oxygen and hydrogen atom(s) in your complex equations; "GEORA" & "LEORRA" (Gain Electron Reduction Oxidizing Agent, Lose Electron Oxidation Reducing Agent)*. As it can be seen, one topic can be expressed with a number of different mnemonic devices corresponding to different mnemonic techniques. Furthermore, even graphical interpretation of the table of standard reduction potential can be used in

⁷ W.DeLoach, *Chemical Mnemonic Devices*, Journal of Chemical Education 1960, 37, p. 367-368.

⁸ M. G.Flipper, Morris K. B., *Helpful aids in the study of chemistry*, Journal of Chemical Education 1945, 22, p. 276-278.

⁹ J.Bermingham, *Mnemonic devices in chemistry*, Journal of Chemical Education 1939, 16, p. 516-517.

¹⁰ K. L Higbee., Kunihira S., *Cross-cultural applications of yodai mnemonics in education*, Educational Psychologist 1985, 20, p. 57-64.

¹¹ M. A.Mastropieri, Scruggs T. E.; Graetz J., *Cognition and learning in inclusive high school chemistry classes, Cognition and learning in diverse settings : Advances in learning and behavioral disabilities*; Scruggs T. E., Mastropieri M. A., Eds.; Oxford, Elsevier Science/JAI Press: United Kingdom, 2005, Vol. 18, p. 107-118.

¹² MobileReference: *Chemistry Study Guide Mobi Study Guides*, 2007.

order to consolidate reduction – oxidation processes¹³. Memorising information consisting of a sequence also can be adopted to chemistry teaching. For example, reactivity series of metals can be coded in the following way: *Katy's Naughty Cat Mingles with Alice and Zarina, Fearlessly plundering her Cupboard of Silver and Gold*¹⁴ and the sequence of lanthanide elements corresponds to the sentence: *Ladies Can't Put Nickels Properly into Slot-machines. Every Girl Tries Daily, However, Every Time You Look*¹². Moreover, the sequence of electron-integrals in quantum chemistry can be remembered by mnemonic device¹⁵. The impact of graphical impression is also acknowledged in the construction of mnemonic devices. In chemistry, the Hückel or Möbius systems can be represented by appropriate circles¹⁶. Also the ground-level configuration for most metals can be remembered with the use of so-called diagonal mnemonic device¹⁷ or simply with the periodic table transformed to mnemonic device¹⁸. Fieberg & Girard (2011)¹⁹ give an example of a graphical mnemonic ('The Energy Pie') for the thermodynamic state variables and Maxwell relations. Shubert & Leyba (2013)²⁰ are describing several mnemonic devices for remembering structure of sugars. In order to memorise such structures one can use a short sentence or computational rules in association with the image of one's hand. Mnemonic device in form of SOS mnemonic is reported by Starkey²¹ for the glucose of stereochemistry. Sell (2003)²² introduces the basis of carbocation chemistry with the use of *The 4-3-2-1 Rule* which corresponds to reaction types and factors influencing them. The tautomerization mechanisms can also be introduced to the students with mnemonic device²³. Kozliak²⁴ compares chemical formula to a certain animal which forms the basis of mnemonic device for the tricarboxylic acid cycle. Foundation on which mnemonic device is constructed can also reflect the concept behind it, for example twelve principles of green chemistry can be "coded" with a single word PRODUCTIVELY^{25,26} gives the example of

¹³ J.Kenkel, *Analytical Chemistry for Technicians*; CRC Press, 2013.

¹⁴ O. H.Leong, *Know Your 'O' Level Chemistry - A Study Guide*; Panpac Education Pte Ltd., 2008.

¹⁵ [A.Szabo, *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Courier Dover Publications, 1996.](#)

¹⁶ E. R.Davison, *Modern Electronic Structure Theory and Applications in Organic Chemistry*, World Scientific, 1997.

¹⁷ R. G.Mortimer, *Physical Chemistry*, Academic Press, 2000.

¹⁸ S. T.Mabrouk, *The Periodic Table as a Mnemonic Device for Writing Electronic Configurations*, Journal of Chemical Education 2003, 80, p. 894-898.

¹⁹ J. E.Fieberg, Girard C. A., *Mnemonic Device for Relating the Eight Thermodynamic State Variables: The Energy Pie*, Journal of Chemical Education 2011, 88, p. 1544-1546.

²⁰ D.Shubert, J.Leyba, *Chemistry and Physics for Nurse Anesthesia*, Springer Publishing Company, 2013.

²¹ R.Starkey, *SOS: A mnemonic for the stereochemistry of glucose*, Journal of Chemical Education 2000, 77, p. 734.

²² C.Sell, *A Fragrant Introduction to Terpenoid Chemistry*, Royal Society of Chemistry, 2003.

²³ C. E. Stephens, *A Simple Mnemonic for Tautomerization Mechanisms in Organic Chemistry*, Journal of Chemical Education 2011, 87, p. 1186-1187.

²⁴ E. I.Kozliak, *Citrate as a Flying Bird: Useful Mnemonics in Teaching the TCA Cycle*, Journal of Chemical Education 1999, 76, p. 1656.

²⁵ [J. A.Tao, Kazlauskas, *Biocatalysis for Green Chemistry and Chemical Process Development*, John Wiley & Sons, 2011.](#)

sentence that helps remembering seven diatomic elements (*Horses Need Oats For Clear Brown I's*), but in their book the reader can find particularly important statement regarding remembering something through something else. Reliance on mnemonic devices will be unabated as experience is gained in their use. Mnemonic devices in chemistry has been noted more than 50 years ago, when²⁷ published short (but detailed) review on the topic of mnemonics in chemistry education.

Interesting example of application the mnemonic methods in chemistry learning and teaching can be conception how to remember eight D-aldohexoses – Figure 1.

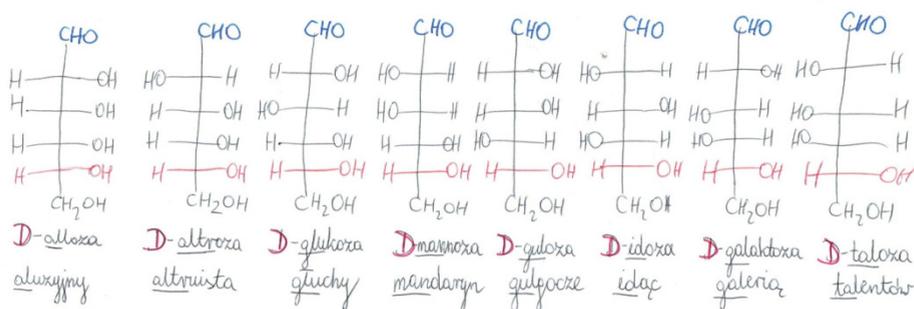


Fig.1. The idea of chemical mnemonic device according to remembering eight D-aldohexoses. This example is a scan of cartoon drawn by pupil preparing for the international secondary-school certificate in chemistry from one Upper Secondary School in Mazowieckie.

4.2 Mnemonic methods in biology teaching and learning

The science education, especially - biology, is becoming more challenging due to richer and more rigorous content demands. Biology is a kind of subject that requires lot information to memorize. On the other hand, the field of research into alternative conceptions in biology is still emerging as compared with efforts in the physical sciences^{28,29}. Due to these facts, the mnemonics methods are very useful and attractive tool for biology learning and teaching.

The teachers of biology, using mnemonics, utilize highly structured procedures for learning efficiency. The use of structure including frequency, replication, rehearsal, and

²⁶ M.Cracolice, E. Peters, *Introductory Chemistry: An Active Learning Approach*, Cengage Learning, 2009.

²⁷ W. DeLoach, *Chemical Mnemonic Devices*, *Journal of Chemical Education* 1960, 37, p. 367-368.

²⁸ K. Tanner, D. Allen, *Approaches to Biology Teaching and Learning: Understanding the Wrong Answers - Teaching toward Conceptual Change*, *Cell Biology Education* 2005, 4, p. 112-117.

²⁹ K. Tanner, D. Allen, *Approaches to Biology Teaching and Learning: Learning Styles and the Problem of Instructional Selection - Engaging All Students in Science Courses*, *Cell Biology Education* 2004, 3, p. 197-201.

monitoring have value in the learning routines of students with learning disabilities directly translating to increased language growth³⁰.

Interesting example of application the mnemonic methods in biology learning and teaching can be acronym "FARMA-B". This example of course is based on abstract word encoding the method. The acronym "FARMA-B" represents the five classes of vertebrate animals: fish, amphibian, reptile, mammal, and bird³¹. However, the "B" letter for bird does not really fit, but it can be "smartly" added to end of acronym. The Figure 2. represents an idea of this example.

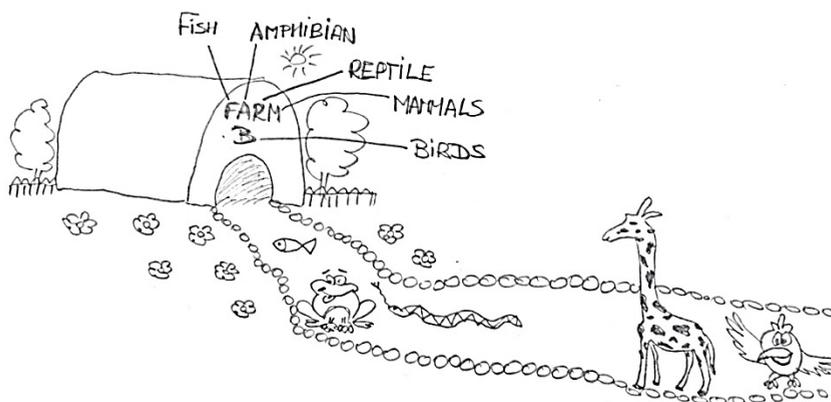


Fig. 2. "FARMA-B" - five classes of vertebrate animals: fish, amphibian, reptile, mammal, and bird based on³¹. This example is a scan of cartoon drawn by pupil preparing for the international secondary-school certificate in biology from one Upper Secondary School in Mazowieckie.

Another example of mnemonics method in biology learning can be a concrete word encoding method applied to remember terms connected with the nervous system. The Figure 3 A – B presents the examples of scans of cartoons drawn by pupils preparing for the international secondary-school certificate in biology from one anonymous Upper Secondary School in Mazowieckie. The Figure 3A presents the idea how to remember a term – synapse. The synapse is found at the end of the axon; there is the space between two neurons or between one neuron and a muscle. The visual connection between the "naps" - part of the word "synapse" and picture with someone who taking a nap between two neurons has been drawn. On the other hand, Figure B presents an example how to remember

³⁰ T. Scruggs, M.Mastropieri, *The Effectiveness of Mnemonic Instruction for Students with Learning and Behavior Problems: An Update and Research Synthesis*, Journal of Behavioral Education 2000, 10, p. 163-173.

³¹ M. T. S.Mastropieri, *Enhancing School Success with Mnemonic Strategies*, Intervention in school and clinic 1998, 33, p. 201-209.

a term - Synaptic Vesicles. The synaptic vesicles are found at the end of the axon (which is sometimes called the terminal button). The synaptic vesicles contain the neurotransmitters. In this example we can go with the obvious (i.e. "testicles"), but also with "vehicles" and the people in the vehicles can be the neurotransmitters.

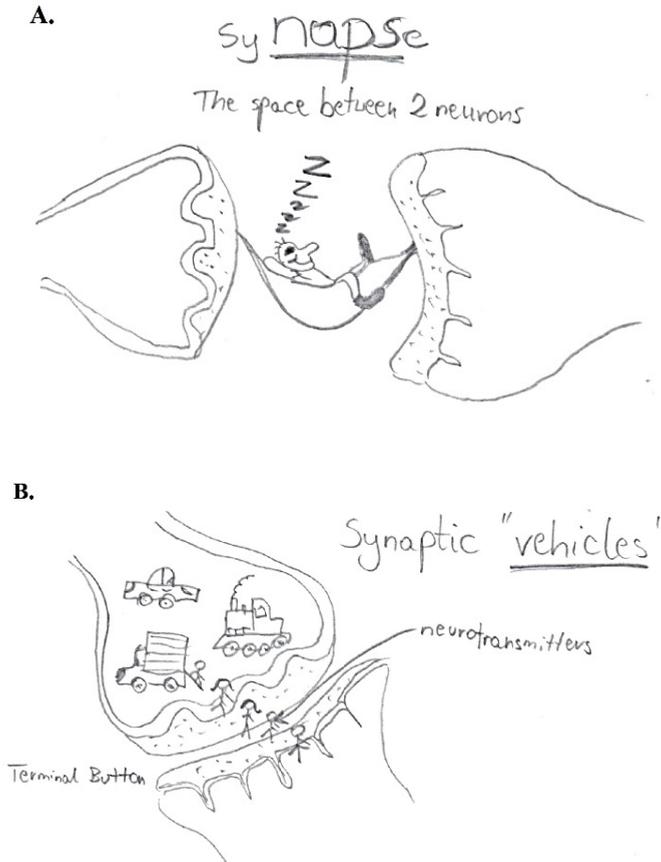


Fig. 3. The examples of mnemonic method to memorize terms: A. Synapse, B. Synaptic Vesicles. This example is a scan of cartoons drawn by pupil preparing for the international secondary-school certificate in biology from one anonymous Upper Secondary School in Mazowieckie.

More sophisticated examples of application mnemonic methods in biology learning can be an abstract word encoding – phonetic encoding to memorize neurotransmitters action - the Figure 4. A – D.

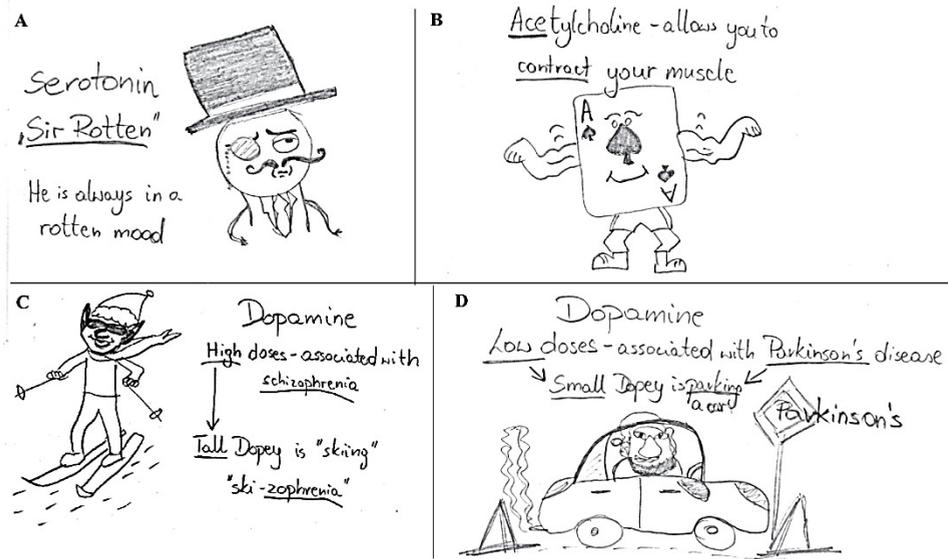


Fig. 4. The examples of mnemonic method to memorize neurotransmitters action. A – Serotonine, B – Acetylocholine, C – Dopamine – high doses, D – Dopamine – low doses. This example is a scan of cartoons drawn by pupil preparing for the international secondary-school certificate in biology from one anonymous Upper Secondary School in Mazowieckie.

Figure 4 A. shows the idea how to remember the action of low level of serotonin. The low level of serotonin in the brain is connected with depression. In this case the pupil draws “Sir Rotten” who is in a rotten mood (depressed). On the other hand - Figure 4 B. presents the way to memorize how acetylcholine works in muscle. Because acetylcholine is involved in helping contract our muscles, it is possible to draw an ACE flexing his muscles as mnemonic. Another neurotransmitter – dopamine, has different action depending on the level. High level is associated with schizophrenia – figure 4 C presents very easy, but useful idea based on a skiing tall dwarf (“ski-zophrenia”) as a good example of pupils ingeniousness. Low level is associated with Parkinson’s disease. Hence, application of the small dwarf “dopey” when he is parking (low – small, parking – Parkinson) is a good mnemonic – Figure 4 D.

4.3. Mnemonic devices in physics

Teaching physics is based on inter alia, conducting experiments and the use of mathematical apparatus to describe the different phenomena and transformations. The students should acquire knowledge of physics in the form of concepts and laws of physics.

On the other hand, many elements of physics is also visible on mathematics, e.g. units and their conversion; students will also learn prefixes used in these units. On website

we can find many examples of different kind of mnemonics for physics. These strategies help students remember principles, rules and procedures.

The most common and useful mnemonics, briefly covered some topics in physics core curriculum are presented below.

For example, it is possible to apply an abstract word encoding – semantic encoding. The Figure 5. presents the order of color coding on electronic resistors³².

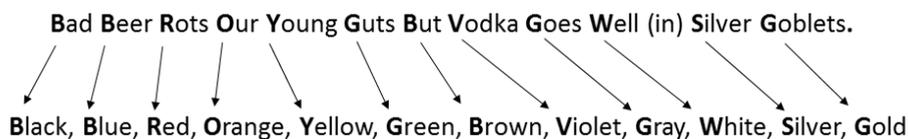


Fig. 5. The example of mnemonic to remember order of color coding on electronic resistors. This example is an idea described by pupil preparing for the international secondary-school certificate in physics from one Upper Secondary School in Mazowieckie.

Another example is the idea how to remember the colors of visible light (for the colors of the rainbow) acronym mnemonic is used³³:

ROY G. BIV (Red, Orange, Yellow, Green, Blue, Indigo, Violet)

Moreover, in this example from left to right, they are arranged from lowest to highest frequency.

On the other hand, the phrase "We guarantee certainty, clearly referring to this light mnemonic" represents the speed of light in meters per second through the number of letters in each word: 299792458 m/s³⁴.

Very popular idea, used by physics students to remember the Maxwell relations in thermodynamics, is "Good Physicists Have Studied Under Very Fine Teachers"³⁵, which helps them remember the order of the variables in the square, in clockwise direction.

To memorize some of formulas and relations grouping them phonetically into one word or sound should be used. For example:

Voltage = Current Resistance $V = IR$ "vir" rhymes with stir.

³² S. Prakash, Physics 2006, 1 and 2, p. 254.

³³ J. A. McCabe, K. L. Osha, J. A. Roche, Susser, *Psychology Students' Knowledge and Use of Mnemonics*, Teaching of Psychology 2013, 40, p. 183-192.

³⁴ J. Parkinson, *i before e (except after c)*; Michael O'Mara Books Limited: Great Britain, 2007.

³⁵ J. C. Zhao, *A mnemonic scheme for thermodynamics*, MRS Bulletin 2009, 34, p. 92-94.

A very simple and popular way in Polish schools (gymnasiums) to algebraically rearrange some formulas is to use a “magic triangle” and fingertip. Although this should be a mathematical piece of cake for most students, it can be used to quickly check for errors. For example a formula such as Ohm’s law: $V=I \cdot R$ can be arranging it in the parts of a triangle as shown below:

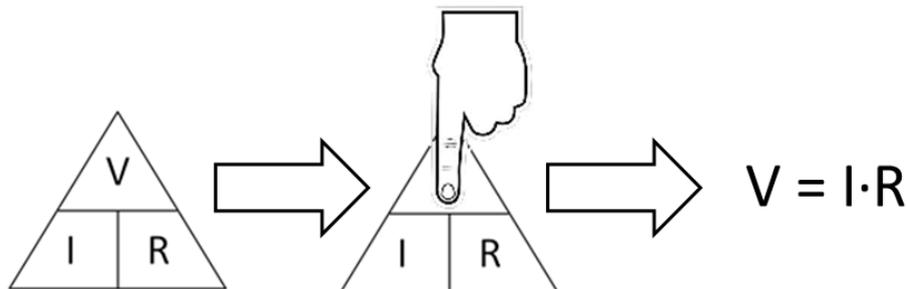


Fig. 6. The example of application “magic triangle”. This example is an idea described by pupil preparing for the international secondary-school certificate in physics from one Upper Secondary School in Mazowieckie.

The next example helps students remember the metric prefixes³⁶ – Figure 7.

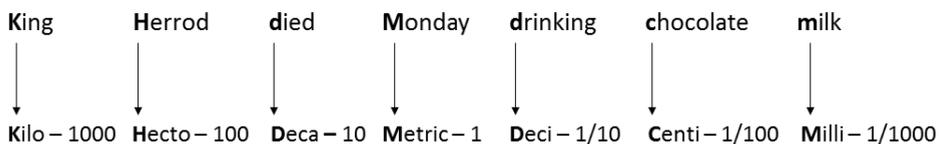


Fig. 7. The example how to remember the metric prefixes. This example is an idea described by pupil preparing for the international secondary-school certificate in physics from one Upper Secondary School in Mazowieckie.

4.4 Mnemonic methods in mathematics teaching and learning

In general opinion math can be too difficult for many students, especially those with learning disabilities. Some students have more difficult time understanding mathematical concepts and retaining information than the others. An exemplary solution that can help students become successful in math is mnemonics. Mnemonic devices used in math can help students having trouble, as well as students with disabilities, and added tool to help in

³⁶ K. A. Kleinheksel, S. E. Summy, *Enhancing Student Learning and Social Behavior Through Mnemonic Strategies*, TEACHING Exceptional Children 2003, 36, p. 30-35.

the learning process various mathematical concepts, including simple mathematics equations³⁷.

There have been many research studies done to validate the use of mnemonics in mathematics instruction. Mnemonics improve recall and learning, especially in students with learning disabilities. Mnemonics help students develop better ways to take in, or encode information, so that it will be much easier to remember, or retrieve.

Different kinds of mnemonics have been used during mathematic lessons. In literature e. g.³⁸ and on websites many examples have been found. Deborah Ball wrote "because some students to be weak, even "math disabled," ... giving pupils tricks, mnemonics, and shortcuts, as well as walking them through the procedures over and over"³⁹. Emmanuel Manalo also considered mathematic learning disabilities: "The clear findings here are that, ... using process mnemonic strategies (i.e., stories, characterizations, scenarios, and other metaphors), but keeping the demonstration and imitation components, proved effective in facilitating not only "learning what to do" in computation but also "remembering what to do" in the long term."³⁷

The method of analytic substitutions consists of translating the material to be remembered into a form that is easier to remember. This translation may involve numbers, sounds, words, and so forth. The most common type of mnemonic is the word-length mnemonic in which the number of letters in each word corresponds to a digit.

Many mnemonics have been devised to help lesser mortals remember the first digits in the decimal expansion of π ; $\pi = 3.141592653589793238462643383279\dots$ In these mnemonics, the number of letters in successive words gives the digits in the expansion. For example, the first eight figures can be obtained from:

May I have a large container of coffee? Another mnemonic, due to Sir James Jeans, is:

How I want a drink, alcoholic of course, after the heavy chapters involving quantum mechanics^{40,41}. Kathy DeLashmutt Hastings describes that the following letter strategy or acronym for the correct order of operations of an algebra problem is very useful way.

This example suggests that mnemonics help many students, but not all of them. Some of the students would rather just learn the math concepts, instead of having to learn a form of mnemonics to remember the concepts. Some of lower students used the mnemonics to help retain key mathematics concepts. Many teachers apply mnemonics in classes to help some of weak students retain science and language arts concepts. For example - the mnemonic BODMAS (Big Old Dot Made A Shot) helps in remembering the sequence

³⁷ E. Manalo, J. K. Bunnell, J. A. Stillman, *The Use of Process Mnemonics in Teaching Students with Mathematics Learning Disabilities*, Learning Disability Quarterly 2000, 23, p. 137-156.

³⁸ W. Gough, *The use of mnemonics in mathematics and physics*, Phys. Educ. 1977, p. 385.

³⁹ B. D. Loewenberg, *Research on teaching mathematics: making subject matter knowledge part of the equation*, Advances in research on teaching, Brophy I. J., Ed.; JAI Press.: Greenwich, CT, 1991, Vol. 2, p. 1-47.

⁴⁰ M. Gardner, *Memorizing Numbers*, The Scientific American Book of Mathematical Puzzles and Diversions; Simon and Schuster: New York, 1959.

⁴¹ D. Blatner, *The Joy of Pi*; Walker: New York, 1997.

of function from left to right: BODMAS → Bracket, Open, Division, Multiplication, Addition, Subtraction”

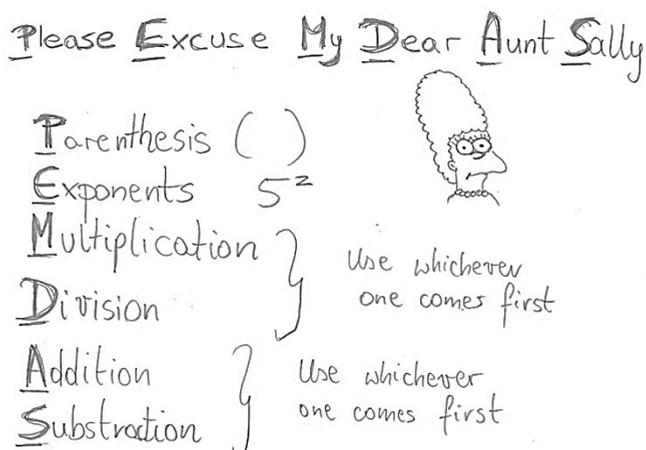


Fig. 8. The example how to remember the sequence of mathematical operations: parenthesis, exponents, multiplication, division, addition and substraction, as a mnemonic. This example is a scan of cartoon drawn by pupil preparing for the international secondary-school certificate in mathematics from one anonymous Upper Secondary School in Mazowieckie.

About the use of mnemonics as an aid to learning statistics, some examples we can find in article “Using mnemonics in Teaching Statistics”⁴².

5. Conclusions

Mnemonic strategies organize and integrate the transformation of difficult to remember information into something that is more meaningful for individuals to recall at a later date by using associations between new and previously learned information in long-term memory.

Mnemonics can assist pupils not only to remember but also to apply intellectual processes. Some literature on mnemonics mentioned above underline that mnemonics facilitate learning process in the beginning, can be of great help in the early stages of developing students’ knowledge. If some information has any meaning, there is a need to combine this learning technique with the use of strategies which are appropriate for meaningful learning.

⁴² N. Hunt, *Using mnemonics in Teaching Statistics*, Teaching Statistics 2010, 32, p. 73-75.

Acknowledgements

This article was made by the support of **Anna Jurowska** and **Kamil Jurowski** scholarship by the **Marian Smoluchowski Kraków Research Consortium "Matter-Energy-Future"** granted the status of a Leading National Research Centre.

The authors would like to thank all anonymous students, pupils and teachers for their helpful works and cartoons for this paper as examples of mnemonics methods.

References

- Bellezza F., *Mnemonic Devices Classification, Characteristics, and Criteria, Review of Educational Research*, Review of Educational Research 1981, 51.
- Bellezza F., *Mnemonic Methods to Enhance Storage and Retrieval*, Memory - Handbook Perception and Cognition; Carterette, E. C. Friedman, M. P. Eds.; Academic Press: Los Angeles, California, 1996.
- Bermingham J., *Mnemonic devices in chemistry*, *Journal of Chemical Education* 1939, 16.
- Blatner D., *The Joy of Pi*; Walker: New York, 1997.
- Cracolice M., Peters, E., *Introductory Chemistry: An Active Learning Approach*, Cengage Learning, 2009.
- Davison E. R., *Modern Electronic Structure Theory and Applications in Organic Chemistry*, World Scientific, 1997.
- DeLoach W., *Chemical Mnemonic Devices*, *Journal of Chemical Education* 1960, 37.
- Fieberg J. E., Girard C. A., *Mnemonic Device for Relating the Eight Thermodynamic State Variables: The Energy Pie*, *Journal of Chemical Education* 2011, 88.
- Flipper M. G., Morris K. B., *Helpful aids in the study of chemistry*, *Journal of Chemical Education* 1945, 22.
- Gardner M., *Memorizing Numbers*, *The Scientific American Book of Mathematical Puzzles and Diversions*; Simon and Schuster: New York, 1959.
- Gough W., *The use of mnemonics in mathematics and physics*, *Phys. Educ.* 1977.
- Guthrie J., *Encyclopedia of Education*, Macmillan Reference 2002.
- Higbee K. L., Kunihiro S., *Cross-cultural applications of yodai mnemonics in education*, *Educational Psychologist* 1985, 20.
- Hunt N., *Using mnemonics in Teaching Statistics*, *Teaching Statistics* 2010, 32, p. 73-75.
- Kenkel J., *Analytical Chemistry for Technicians*; CRC Press, 2013.
- Kleinheksel K. A., Summy S. E., *Enhancing Student Learning and Social Behavior Through Mnemonic Strategies*, *TEACHING Exceptional Children* 2003, 36.
- Kozliak E. I., *Citrate as a Flying Bird: Useful Mnemonics in Teaching the TCA Cycle*, *Journal of Chemical Education* 1999, 76.
- Leong O. H., *Know Your 'O' Level Chemistry - A Study Guide*; Panpac Education Pte Ltd., 2008.

- Levin M., Levin J., *Scientific mnemonics: Methods for maximizing more than memory*, *Am Educ Res J.* 1990, 27.
- Loewenberg B. D., *Research on teaching mathematics: making subject matter knowledge part of the equation*, *Advances in research on teaching*, Brophy I. J., Ed.; JAI Press.: Greenwich, CT, 1991, Vol. 2.
- Mabrouk S. T., *The Periodic Table as a Mnemonic Device for Writing Electronic Configurations*, *Journal of Chemical Education* 2003, 80.
- Manalo E., Bunnell J. K., Stillman J. A., *The Use of Process Mnemonics in Teaching Students with Mathematics Learning Disabilities*, *Learning Disability Quarterly* 2000, 23.
- Mastropieri M., Scruggs T., *Text Versus Hands-On Science Curriculum Implications for Students with Disabilities*, *Remedial and Special Education* 1994, 15.
- Mastropieri M. T. S., *Enhancing School Success with Mnemonic Strategies*, *Intervention in school and clinic* 1998, 33.
- Mastropieri M. A., Scruggs T. E.; Graetz J., *Cognition and learning in inclusive high school chemistry classes*, *Cognition and learning in diverse settings : Advances in learning and behavioral disabilities*; Scruggs T. E., Mastropieri M. A., Eds.; Oxford, Elsevier Science/JAI Press: United Kingdom, 2005, Vol. 18.
- McCabe J. A., Osha K. L., Roche J. A., Susser J. A., *Psychology Students' Knowledge and Use of Mnemonics*, *Teaching of Psychology* 2013, 40.
- MobileReference: *Chemistry Study Guide Mobi Study Guides*, 2007.
- Mortimer R. G., *Physical Chemistry*, Academic Press, 2000.
- Parkinson J., *i before e (except after c)*; Michael O'Mara Books Limited: Great Britain, 2007.
- Prakash S., *Physics* 2006, 1 and 2.
- Scruggs T., Mastropieri M., *The Effectiveness of Mnemonic Instruction for Students with Learning and Behavior Problems: An Update and Research Synthesis*, *Journal of Behavioral Education* 2000, 10, p. 163-173.
- Sell C., *A Fragrant Introduction to Terpenoid Chemistry*, Royal Society of Chemistry, 2003.
- Shubert D., Leyba J., *Chemistry and Physics for Nurse Anesthesia*, Springer Publishing Company, 2013.
- Starkey R., *SOS: A mnemonic for the stereochemistry of glucose*, *Journal of Chemical Education* 2000, 77, p. 734.
- Stephens C. E., *A Simple Mnemonic for Tautomerization Mechanisms in Organic Chemistry*, *Journal of Chemical Education* 2011, 87.
- Szabo A., *Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory*, Courier Dover Publications, 1996.
- Tanner K., Allen D., *Approaches to Biology Teaching and Learning: Learning Styles and the Problem of Instructional Selection - Engaging All Students in Science Courses*, *Cell Biology Education* 2004, 3.
- Tanner K., Allen D., *Approaches to Biology Teaching and Learning: Understanding the Wrong Answers - Teaching toward Conceptual Change*, *Cell Biology Education* 2005, 4.

Tao J. A., Kazlauskas R. J., *Biocatalysis for Green Chemistry and Chemical Process Development*, John Wiley & Sons, 2011.

Zhao J. C., *A mnemonic scheme for thermodynamics*, MRS Bulletin 2009, 34.

Appendix 1.

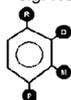
Questionnaire about methods of remembering and memorizing the information

Complete the questionnaire writing suitable answers. Questionnaire is anonymous, the results will become used in scientific article. After the mark of the answer do not return to previous questions(!)

1. Your gender and (Place an 'X' in appropriate box): Male / Female
2. I am years old and my race/ethnicity is (Place an 'X' in appropriate box): European / Asian / Other
3. 1. Do you know what are mnemonic devices/methods? (Place an 'X' in appropriate box): Yes / No
3. 2. If You choice "Yes" in question 3.1, explain in Your own word what are?

4. Below are presented different types of mnemonic methods with examples. Do you know some of them? (Place an 'X' in appropriate boxes or leave empty fields)

- Rhyme** - a rhyme is a poem or verse that uses words that end with the same sound; e.g.
*Twinkle, twinkle little star,
circumference is 2 pi r;
I didn't really know you cared,
area is pi r squared.*
- Acronym** - an acronym is a word that can be pronounced that is made by using the first letter of other words;
e.g. **C**ARBO - Cathode **A**node **R**eduction **O**xidation.
- Abbreviation** - an abbreviation is a group of letters made from the first letter of each word to be remembered;
e.g. **ABC** for remember the most important acts of the first-aid **A** - Airways, **B** - breath, **C** - circulation.
- Acrostic** - an acrostic sentence or phrase is formed by words beginning with the first letter of each word to be remembered: e.g. **A**ll **A**ltruists **G**ladly **M**ake **G**um **I**n **G**allon **T**anks for remember the aldohexoses **A**llose, **A**lucose, **G**lucose, **M**annose, **F**ructose, **G**ulose, **I**dose, **G**alactose **T**alose.
- Pegwords** - a pegword is a word that helps you remember something by forming a picture in your mind;
e.g. **ROMP**: **R** - alkyl group, **O** - ortho, **M**-meta and **P** - para according to below picture



5. Which method most often do you use?
 Rhyme / Acronym / Abbreviation / Acrostic / Pegwords / No one
6. How often you use mnemonic methods during the learning?
 Never
 Only when it is given by the teacher
 Sporadically - mostly when other methods disappoint
 Always (I use and invent own examples)
 Other option (write Your option)
7. On what subject did you use examples which can be a mnemonics device? (Place an 'X' in appropriate box/es or leave empty fields)
 Biology / Chemistry / Physics / Mathematics / none /
 Other (which one?)
8. Give the any example/s being with the mnemonics which most often you use or which best you remember (Use the retreat of the card).

We thank You very much for the participation in this questionnaire!

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Mnemonic methods as a sophisticated tool in learning the science subjects from Polish pupils point of view

Mnemonic devices can be defined as learning strategies which can often enhance the learning and later recall of information. On the other hand, mnemonic systems are special techniques or strategies consciously used to improve memory, it helps employ information already stored in long-term memory to make memorization an easier task. There is no doubt that mnemonic techniques are the one of the most important methods used in education, however in nowadays these methods seem to be unremembered and seldom used by teachers, students or pupils. Moreover, there is a lack of actual studies about this subject – especially according to Polish pupils. In this article we described the examples of mnemonic devices as a sophisticated tool in learning the science subjects from Polish pupils' point of view.

Keywords: mnemonics methods, science education, mnemonics, memory

Metody mnemotechniczne jako wyrafinowane narzędzie w uczeniu przedmiotów przyrodniczych z punktu widzenia polskich uczniów

Metody mnemotechniczne mogą być zdefiniowane jako strategie w uczeniu się, które często wzmagają naukę oraz późniejsze przywołanie informacji. Z drugiej strony, systemy mnemotechniczne są specjalnymi technikami lub strategiami świadomie używanymi do polepszenia pamięci; techniki te pomagają zaangażować informacje już przechowywane w pamięci długotrwałej w celu łatwego zapamiętania wiadomości. Niewątpliwie techniki mnemotechniczne są najważniejszymi metodami w edukacji, jednakże obecnie metody te zostały zapomniane i rzadko stosowane przez nauczycieli, studentów i uczniów. Ponadto, brak jest aktualnych badań naukowych na ten temat - szczególnie w odniesieniu do polskich uczniów. W artykule tym opisaliśmy przykłady metod mnemotechnicznych jako wyrafinowanych metod w uczeniu się przedmiotów przyrodniczych z punktu widzenia polskich uczniów.

Słowa kluczowe: metody mnemotechniczne, edukacja przyrodnicza, mnemonika, pamięć

Przetłumaczone przez Małgorzatę Krzeczowską