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Self-learning by Using Code-Based Games: An Easy Way to Learn Biomolecule's Nomenclature

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Abstract

The Montessori method was an educational model devised at the beginning of the 20th century by the Italian pedagogue, physician, psychologist, and psychiatrist María Montessori (1870-1952). She observed that her students activated their intelligence and developed their personality by carrying out manual activities. In recent years, one of the activities that she used, gamification, is currently booming in teaching. Games based in words or letters are often used in language learning, either in presential lessons or in mobile applications. In our teaching innovation group (GINDOC-UB/180), we proposed to adapt those word games using codes so that students could achieve a self-learning on the nomenclature of biomolecules, thus improving their knowledge in metabolism. These code-based games were proposed to Biochemistry students at the Chemistry degree of the Universitat de Barcelona. Games were posted on the Virtual Campus using Moodle. A code is part of a communicative system, and it is defined as a set of elements that allows a message to be decoded. In biochemistry, the best-known code is the genetic code that translates 3 nucleotides to an amino acid. The code allows the students to see that it is a degenerated code, and it was the first code-based game used. Nevertheless, only 20 amino acids are involved, and some letters are missing. Thus, we also used other codes such as numeric codes, Morse code, Braille system code, or codes from other alphabets (Japanese katakana or hiragana, Cyrillic alphabet, Arabic alphabet, or runic alphabet). In this work some examples of the games that can be proposed to the students are shown. Proposed games were highly valued by students and allowed a self-learning on the proposed biomolecules. Games based on the genetic code were easier and more enjoyable for the students to solve, and they provided them with additional biochemical knowledge of protein translation.

Introduction

Although the Montessori method was initially used as a method of educating students up to the age of 18, the method can also be applied to university students. The method is characterized by creating an environment divided into thematic areas, with shelves containing material and bibliography related to a certain thematic area. The environment promotes learning, as the student explores between the material and the bibliography of the subject.

To facilitate learning, the teacher must observe the interests of each student and encourage their personal fulfillment in each case [1]. In this sense, games for self-learning and several other materials can be included within the Moodle environment. The Moodle environment can be organized by themes, containing different types of games, so that the student can choose between them. In addition, this environment also makes it possible to identify how many times and in what types of topics has each student been most interested on. Thus, Moodle allows the use of Montessori method, being able to analyze the games most used by a particular student, or by the group of students. Innovation by applying games (gamification) has not been applied very often in science subjects, such as “Biochemistry”.

However, numerical problems are commonly more used to teach science, and since many of them are solved by repetitive algorithms, it is possible to consider numerical problems as if they were alternative games. Word games are mainly used to learn foreign languages or grammar, but since the nomenclature of biomolecules in Biochemistry is complex and difficult to remember, we thought that it was also possible to use them also in science items. In a previous work we classified these games into 4 main groups: a) words lacking a syllable or a group of letters, b) anagrams and mazes, c) translations using codes, d) dominoes and other games to chain words [2].

A study of the codes that can be applied to Biochemistry word games was essential to prepare new games within this third main group (translations using codes). In this paper, we show some examples of games based on codes, that can be used to self-learning the biomolecules’ nomenclature. In addition, in order that students could also learn other aspect of biomolecules’ structures, some additional questions regarding the structure were also asked in the games.

The main aim of the paper was to develop codes, to prepare games that contain biomolecules’ nomenclature and structure. To achieve the main aim, we proposed the following objectives: a) To look for different codes systems in order to decipher the names of biomolecules; b) To adapt the games and to propose these games to the Biochemistry item; c) To obtain an added value to the games, proposing other questions related to the structure of the biomolecules. In this paper, we present some examples regarding these code-based games.

Method

First, we choose the main biomolecule names, by using Biochemistry glossaries of the most common biomolecules [3, 4]. Once the biomolecules of interest were located, the following step was to search of the most interesting codes used as a basis for decoding the biomolecules’ nomenclature. Some of the codes were international codes, and thus they were not needed to be included in the game. Nevertheless, other games need to include the code within the game, as they were not easily found. Among the codes, some of the most important are detailed in the following sections.

The Genetic Code

The genetic code [3, 4] allows genes to be translated into proteins. Thus, with the 2 purine bases (adenine A and guanine G) and the 2 pyrimidine bases (cytosine C and uracil U), words with 3 bases are formed. Each 3-base word translates to one of the 20 protein amino acids (see Table 1). This code is degenerated, that is, some amino acids can be translated by several 3-letter words (64 words with 3 letters, but only 20 protein amino acids). Thus, some amino acids are translated by 6 words, other by 4 words, or 2 words; while only one (W) is translated by one 3-bases word (UGG) [5].

Table 1. Genetic Code

	U			C			A			G		
U	UUU	Phe	F	UCU	Ser	S	UAU	Tyr	Y	UGU	Cys	C
	UUC	Phe	F	UCC	Ser	S	UAC	Tyr	Y	UGC	Cys	C
	UUA	Leu	L	UCA	Ser	S	UAA	Stop		UGA	Stop	
	UUG	Leu	L	UCG	Ser	S	UAG	Stop		UGG	Trp	W
C	CUU	Leu	L	CCU	Pro	P	CAU	His	H	CGU	Arg	R
	CUC	Leu	L	CCC	Pro	P	CAC	His	H	CGC	Arg	R
	CUA	Leu	L	CCA	Pro	P	CAA	Gln	Q	CGA	Arg	R
	CUG	Leu	L	CCG	Pro	P	CAG	Gln	Q	CGG	Arg	R
A	AUU	Ile	I	ACU	Thr	T	AAU	Asn	N	AGU	Ser	S
	AUG	Ile	I	ACC	Thr	T	AAC	Asn	N	AGC	Ser	S
	AUA	Ile	I	ACA	Thr	T	AAA	Lys	K	AGA	Arg	R
	AUG	Met	M	ACG	Thr	T	AAG	Lys	K	AGG	Arg	R
G	GUU	Val	V	GCU	Ala	A	GAU	Asp	D	GGU	Gly	G
	GUC	Val	V	GCC	Ala	A	GAC	Asp	D	GGC	Gly	G
	GUA	Val	V	GCA	Ala	A	GAA	Glu	E	GGA	Gly	G
	AUG	Val	V	GCG	Ala	A	GAG	Glu	E	GGG	Gly	G

Note: In Biochemistry, three RNA bases are translated into one amino acid. Amino acids are abbreviated by a three letters code or by one letter code. Regarding word games using this code, not all biomolecules can be named, as the following letters are not encoded: BJOUXZ. This problem can be solved by adding some codes for these 6 letters that don't belong to genetic code.

Genetic code is important in Biochemistry, and therefore this code can give a high impact, as it is not only a simple code to translates letters, but also indicates how the cell is able to translate 3-bases into 1-amino acid. The main problem is that not all the biomolecules' nomenclature can be used in this game code, as some letters are missing (BJOUXZ). The problem can be solved, for example, by using the stop codes for U, and triplets as BBB, JJJ, OOO, XXX and ZZZ for the other missing letters.

Morse Code

Morse code, unlike the previous one, encodes all the letters of the alphabet. This code consists of a method to transmit natural language using only electrical pulses and silence between them. Around 1837, Samuel F.B. Morse, developed a precursor to the modern International Morse code [6], which was first used in 1844. The code was improved in 1848 by Friedrich Clemens Gerke, and the International Morse code was finally generated in 1865. Table 2 shows this international Morse code, and a phonetic alphabet used by radio speakers.

Table 2. International Morse Code

	Code	Phonetic alphabet		Code	Phonetic alphabet		Code	Phonetic alphabet
A	•—	ALPHA	J	•———	JULIET	R	•—•	ROMEO
B	—•••	BRAVO	K	—•—	KILO	S	•••	SIERRA
C	—•—•	CHARLIE	L	•—••	LIMA	T	—	TANGO
D	—••	DELTA	M	——	MIKE	U	••—	UNIFORM
E	•	ECHO	N	—•	NOVEMBER	V	•••—	VICTOR
F	••—•	FOXTROT	O	———	OSCAR	W	•——	WHISKEY
G	——•	GOLF	P	•——•	PAPA	X	—••—	X-RAY
H	••••	HOTEL	Q	——•—	QUEBEC	Y	—•——	YANKEE
I	••	INDIA				Z	——••	ZULU

Note: In which the letters of the alphabet are obtained by short (dots) or long (dashes) electrical pulses. The table also gives an easy word that begins with the letter, to recognize phonetically the different letters.

Braille code

Louis Braille (1809-1852) was accidentally blind at the age of 3 and he studied science and music at the Paris School for blind people. In 1828, as a professor at this School, he modified the system invented in 1821 by Charles Barbier, creating the relief writing and reading system that has got his name. The system is based on groups of 1 to 6 points in relief, which was later slightly modified to create finally the International Braille code shown in Figure 1, where the black points are raised, and the white ones are not.

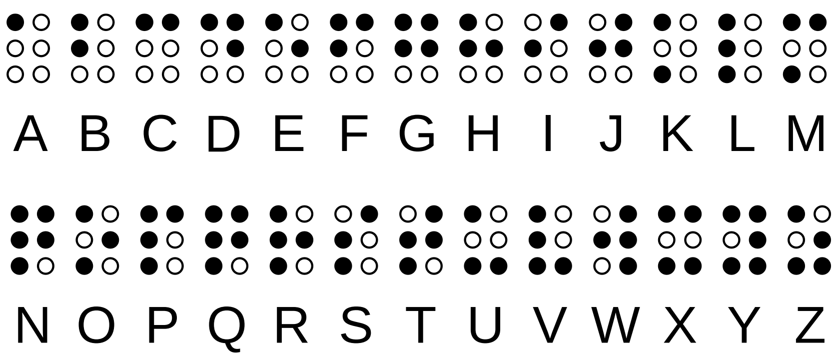


Figure 1. International Braille code, in which raised dots are painted in black. Each letter is represented with 1 to 6 raised dots present in a 2 x 3 matrix.

The Numerical Codes

Other possible codes are those in which each letter is represented by a number. The simplest code consists in numbering each letter in alphabetic order (Figure 2) or numbering inverting the alphabetic order (Figure 3). However, these 2 codes are very simple and are not normally used for secret messages.

A	B	C	D	E	F	G	H	I	J	K	L	M
01	02	03	04	05	06	07	08	09	10	11	12	13
N	O	P	Q	R	S	T	U	V	W	X	Y	Z
14	15	16	17	18	19	20	21	22	23	24	25	26

Figure 2. Numerical code, where the letters are numbered in alphabetical order.

A	B	C	D	E	F	G	H	I	J	K	L	M
26	25	24	23	22	21	20	19	18	17	16	15	14
N	O	P	Q	R	S	T	U	V	W	X	Y	Z
13	12	11	10	09	08	07	06	05	04	03	02	01

Figure 3. Numerical code, where the letters are numbered in reverse alphabetical order.

It is possible to further complicate the numerical codes, by using other possible numberings (Figure 4). In this figure, the numbering starts from a certain letter of the alphabet (in this case, the letter I, instead of the A, is the first one, with number 01). However, the numbering can start from any letter and continue the alphabet from this letter forwards or backwards. It is also possible to number only pair letters and afterwards the remaining letters.

A	B	C	D	E	F	G	H	I	J	K	L	M
19	20	21	22	23	24	25	26	01	02	03	04	05
N	O	P	Q	R	S	T	U	V	W	X	Y	Z
06	07	08	09	10	11	12	13	14	15	16	17	18

Figure 4. Numerical code, where the letters are numbered in alphabetical order, but defining a specific letter as the first one (here, I was number 01).

Another possibility would be to use Roman numbers instead of Arabic numbers. In this case, the game also acquires an added value, so that students could learn or remember the Roman numbers.

Codes with Latin Characters

In a similar way as it is described with codes with numbers, Latin characters can also be used as codes. A simple way consists in displace the letters, such as in the example of Figure 5, where V is codified by A and further continuing in alphabetic order.

Original:	A	B	C	D	E	F	G	H	I	J	K	L	M
Code:	F	G	H	I	J	K	L	M	N	O	P	Q	R
Original:	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Code:	S	T	U	V	W	X	Y	Z	A	B	C	D	E

Figure 5. Code generated with Latin characters, where each letter is coded with the letters located 5 characters beyond in alphabetical order.

Similarly, the letters of the alphabet could be reversed, as in the case of Figure 6. In other more elaborated codes, it could also start with a certain letter and reverse the alphabetical order as well.

Original:	A	B	C	D	E	F	G	H	I	J	K	L	M
Code:	Z	Y	X	W	V	U	T	S	R	Q	P	O	N
Original:	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Code:	M	L	K	J	I	H	G	F	E	D	C	B	A

Figure 6. Code with Latin characters in which the letters are arranged inverting the alphabetical order.

Codes with Other Non-Latin Characters

These kinds of codes could have an added value if the code has identical phonetic in non-Latin characters and in Latin characters. Using thus the non-Latin characters, the student can learn how to read words in other languages that use other characters. In the Arabic or Hebrew alphabet, words are written from right to left, and vowels are represented by dots or omitted if the words are already known by the reader. Thus, these alphabets can be difficult to use as a direct phonetic of words. Japanese syllabaries (hiragana and katakana) can be used as codes more easily than Arabic or Hebrew alphabets, as these syllabaries can be written from left to right. Since Western words or family names are written in Japanese in katakana, it seems more appropriate to use this syllabary rather than hiragana, but hiragana can be also used. Nevertheless, either hiragana and katakana are syllabaries and do not represent a single consonant. Other alphabets, such as the Cyrillic and Greek alphabets, are easier as there are more direct equivalences between the characters of these alphabets and the letters of the Latin alphabet.

On the other hand, codes can be used with characters that do not have a similar phonetic reading to the encoded word. Thus, any character could be used to the letter A, although in the language of the character it is not read as A. In that case, we could also mix Arabic, Hebrew, Japanese, Runic, Cyrillic and Greek characters all together to form a certain code (Figure 7). Another possibility would be to use the ASCII code (American Standard Code for Information Interchange). The ASCII code can be used in its binary, decimal or hexadecimal version [7].

Original:	A	B	C	D	E	F	G	H	I	J	K	L	M
Code:	あ	ば	か	だ	え	א	ל	ם	ש	ט	ב	α	β

Original:	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Code:	γ	δ	ε	π	ا	ب	ج	و	ى	и	ю	я	ж

Figure 7. Code using Japanese syllabary (from A to E), Hebrew (from F to K), Greek (from L to Q), Arabic (from R to V) and Cyrillic (from W to Z) words. In this code, phonetic was not considered, although some letters sounds are phonetically similar.

Other More Complex Codes

In other cases, a coding is possible using, for example, a book (which could be the Biochemistry textbook used for teaching, to add more value to the code) and search for words or letters within the book, which could be defined with a page number, a line number, and a word or letter number within the line. A set of 3 numbers would be enough to encode a letter inside the word (page, line and number of letter or word).

The use of an acrostic can also be applied to identify names of biomolecules. An acrostic is a poem, from which it is possible to obtain a hidden word by writing the initial letters of its verses, the final letters, or the letters in a certain position of each line. An example can be obtained from an acrostic builder [8]. For the word DNA, an acrostic using the first letter of the verses can be, for example:

– Daughters wish you God for your beauty be played,
– nostalgia that you have slanted,
– a failure in love is, for man, as a mission accomplished

However, these types of codes are too complex to prepare easy games. It is more practical to use other simpler codes.

Results

This section shows some examples of code-based games, that could be used by students to self-learning nomenclature and structure of biomolecules in Biochemistry of the Chemistry degree. The codes used to decode the words were classified into the following groups: 1. Genetic code; 2. Morse code; 3. Braille code; 4. Numeric codes; 5. Codes with Latin letters; 6. Other codes with non-Latin characters; 7. Other more complex codes (code from a text or book, or acrostics). In this paper we analyze the encrypted games with these previously classified codes.

In some games it is not necessary to define codes since they are international codes and easy to find on Internet or in general books. In other cases, to facilitate the game resolution, it would be necessary to define codes within the game. Here, we present some examples of games using codes:

Games based on Genetic Code

Since the Biochemistry student can easily find the code in general Biochemistry books [3, 4], genetic code does not need to be displayed within the game. Furthermore, this kind of game allows students also to learn the genetic code while they are playing translating the words. They can learn the one-letter abbreviation of protein amino acids as well. One problem of this code is that, although it is a degenerated code (64 combinations of 3 bases), translates to only 20 letters (the one-letter abbreviation for all 20 protein amino acids). Letters B, J, O, U, X and Z are missing, and therefore it is not possible to codify words containing those letters. This problem can be in general more difficult with the vowels O and U, and especially with O, very often found in biomolecule's endings such as –OSE, for carbohydrates.

Example of a game based on the genetic code

From genetic code, identify the following words by using the abbreviation of one letter of the amino acids coded by the three nitrogenated bases. The words are biomolecule names, most of them amino acids. Which biomolecule is not an amino acid?

Coded words:
GCC-GAU-GAA-AAU-AUU-AAC-GAA
UGU-UAU-AGC-ACA-GAA-AUU-AAC-GAA
GGG-CUA-UAC-UGU-AUU-AAU-GAG
UCC-GAG-AGG-AUA-AAU-GAG
AUG-GCG-CUA-AUA-AAU-GAA

Solution:
ADENINE (nitrogenous base)
CYSTEINE

GLYCINE
SERINE
VALINE

Games based on Morse Code

Morse code is also an international code. Nevertheless, since this code is not related to biochemistry, students must either find the code on Internet, or the code must be given included in the activity. In this case, unlike the previous code, it is possible to encode any word because there is a translation for each letter.

Example of a game based on Morse code

From the international Morse code, identify the following biomolecules. Classify them in the following families: carbohydrates, amino acids, or lipids.

<u>Coded words</u>:
•— ••• •——• •— •—• — •— — •
••—• •—• ••— —•—• — ——— ••• •
——• •—•• ••— —•—• ——— ••• •
•—•• • ••— —•—• •• —• •
——— •—•• • •— — •
•——• •— •—•• —— •• — •— — •

<u>Solution</u>:
ASPARTATE (Amino acid)
FRUCTOSE (Carbohydrate)
GLUCOSE (Carbohydrate)
LEUCINE (Amino acid)
OLEATE (Lipid)
PALMITATE (Lipid)

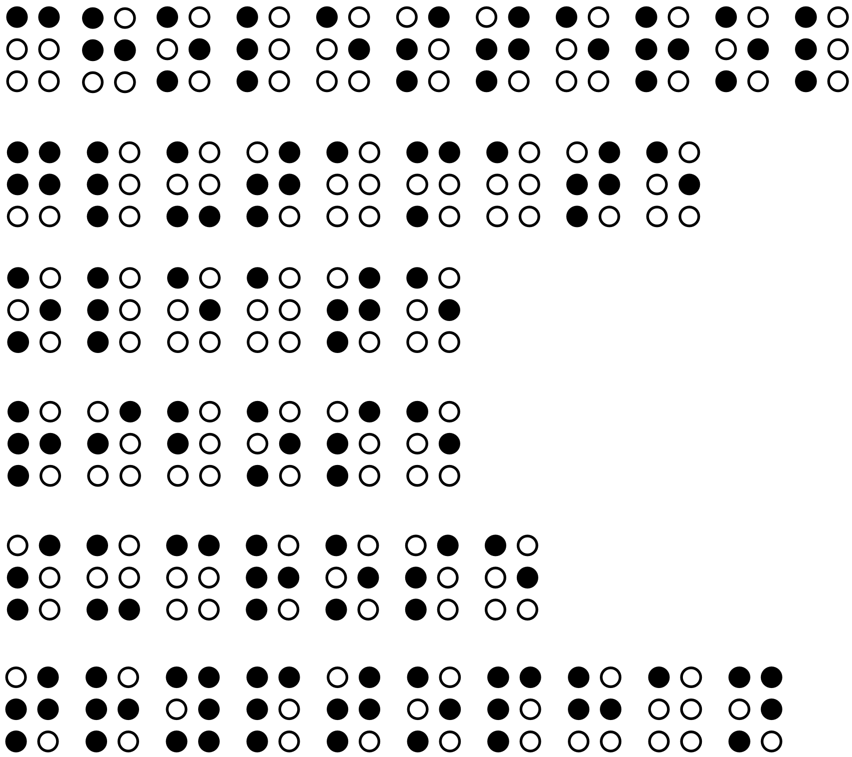
Games based on Braille Code

As it happens with the Morse code, Braille code is also an international code, and students can find it easily in Internet. However, it will be better for students when the code is given as a part of the game.

Example of a game based on Braille code

Using the international Braille code, reveal the names of the following coded biomolecules. Classify them in the following families: carbohydrates, amino acids, or lipids:

Coded words:



Solution:

CHOLESTEROL (Lipid)

GLUTAMATE (Amino acid)

OLEATE (Lipid)

RIBOSE (Carbohydrate)

SUCROSE (Carbohydrate)

TRYPTOPHAN (Amino acid)

Games based on Numerical Codes

Numerical codes can be different, so it is better to define each code as a part of the game. In the following example, a game is proposed in which the numerical code follows alphabetical order.

Example of a game based on a numerical code

Identify the following biomolecules, by using the numerical code shown hereby. Classify them in the following families: carbohydrates, amino acids, or lipids:

Numeric code:

A – B – C – D – E – F – G – H – I – J – K – L – M – N – O – P – Q – R – S – T – U – V – W – X – Y – Z
01– 02 – 03 – 04 – 05 – 06 – 07 – 08 – 09 – 10 – 11 –12 –13 –14 – 15 – 16 – 17 –18 – 19 – 20 –21 – 22 – 23 – 24 – 25 – 26

Coded words:
01-18-01-03-08-09-04-15-14-01-20-05
07-01-12-01-03-20-15-19-05
09-19-15-12-05-21-03-09-14-05
13-25-18-09-19-20-01-20-05
16-18-15-12-09-14-05
24-25-12-21-12-15-19-05

Solution:
ARACHIDONATE (Lipid)
GALACTOSE (Carbohydrate)
ISOLEUCINE (Amino acid)
MYRISTATE (Lipid)
PROLINE (Amino acid)
XYLULOSE (Carbohydrate)

Games based on Codes with Latin Letters

As in the case of numerical codes, codes with Latin letters can also be different, and therefore it is also better to define the code as a part of the game. In the example, a game is proposed in which the code with Latin letters is moved 5 letters further.

Example of a game based on a numerical code

From the game code presented hereby, identify the following coded biomolecules. Classify them in the families of the three immediate principles (carbohydrates, amino acids, or lipids):

Code with letters:

ORIGINAL: A – B – C – D – E – F – G – H – I – J – K – L – M – N – O – P – Q – R – S – T – U – V – W – X – Y – Z
CODE: F– G – H – I – J – K – L– M –N –O – P –Q – R – S – T – U – V – W – X – Y – Z – A – B – C – D – E

Coded words:
FWFGNSTXJ
UMJSDQFQFSNSJ
RFSSTXJ
RJYMNTSNSJ
UWTXYFLQFSINS
YJXYTXYJWTSJ

Solution:

ARABINOSE (Carbohydrate)
PHENYLALANINE (Amino acid)
MANNOSE (Carbohydrate)
METHIONINE (Amino acid)
PROSTAGLANDIN (Lipid)
TESTOSTERONE (Lipid)

Games based on Other Non-Latin Letters Codes

In this type of games, words can be encoded using letters from different alphabets. Although phonetic characters in other languages can be used in order that students could learn how to read using non-Latin letters, sometimes this can be difficult. Hereby, we choose the katakana syllabary in Japanese (see Table 3) in the following example. Nevertheless, other games can be proposed by using a code as that shown in Figure 7.

Example of a game based on the Japanese katakana syllabary

From the katakana syllabary shown in Table 3, identify the following coded biomolecules. Classify them in the families of carbohydrates, amino acids, or lipids:

Coded words:

パルミタテ

ラクトセ

ラノステロル

リシネ

スクロセ

セリネ

Solution:

PALMITATE (Lipid)
LACTOSE (Carbohydrate)
LANOSTEROL (Lipid)
LYSINE (Amino acid)
SUCROSE (Carbohydrate)
SERINE (Amino acid)

Table 3. Katakana Chart Showing 46 Basic Characters and Romanji Translation

a	ア	i	イ	u	ウ	e	エ	o	オ
ka	カ	ki	キ	ku	ク	ke	ケ	ko	コ
ga	ガ	gi	ギ	gu	グ	ge	ゲ	go	ゴ
sa	サ	shi	シ	su	ス	se	セ	so	ソ
za	ザ	ji	ジ	zu	ズ	ze	ゼ	zo	ゾ
ta	タ	chi	チ	tsu	ツ	te	テ	to	ト
da	ダ	di	ヂ	du	ヅ	de	デ	do	ド
na	ナ	ni	ニ	nu	ヌ	ne	ネ	no	ノ
ha	ハ	hi	ヒ	fu	フ	he	ヘ	ho	ホ
ba	バ	bi	ビ	bu	ブ	be	ベ	bo	ボ
pa	パ	pi	ピ	pu	プ	pe	ペ	po	ポ
ma	マ	mi	ミ	mu	ム	me	メ	mo	モ
ya	ヤ			yu	ユ			yo	ヨ
ra	ラ	ri	リ	ru	ル	re	レ	ro	ロ
wa	ワ			n	ン			wo	ヲ

Example of a game based on non-Latin codes

Using the code shown in Figure 7, identify the following coded biomolecules. Classify them in the families of carbohydrates, amino acids, or lipids:

<u>Coded words</u>:

あ α あ γ ש γ え

か ם δ α えب ج え ا δ α

ל α و か δ ب え

ל α و ج あج β ש γ え

ب ε ם ש γ ל δ ب ש γ え

ب ج あ ا かם

Solution:
ALANINE (Amino acid)
CHOLESTEROL (Lipid)
GLUCOSE (Carbohydrate)
GLUTAMINE (Amino acid)
SPHINGOSINE (Lipid)
STARCH (Carbohydrate)

Games based on Other Complex Codes

These types of games are complex to set up and easy to solve. In this case we prepare an acrostic by using the acrostic maker [8]. Another possibility is to prepare a text and locate the correct letters from a code using the number of line and of the letter in the line.

Example of a game based on an acrostic

Find the name of the biomolecule that is hidden behind the first letter of each line of the following verses. Indicate if the biomolecule is a carbohydrate, amino acid, or lipid:

Verses:
Screaming into the morning,
evenings when the sea almost is touching,
rather than to the sane living,
I have no time, but I went with him rotting.
Never try to teach a pig to sing,
eaten in peace and sibling.

Solution:
SERINE (Amino acid)

Example of a text-based game

Find the name of the biomolecule that is hidden behind a code expressed as: line-letter (ignore spaces and non-letter characters) in the poetry in the example. Indicate if the biomolecule is a carbohydrate, amino acid, or lipid.

Coded words:
2-20; 1-5; 5-14; 6-3; 4-7; 3-16, 2-3

Solution:
LACTOSE (Carbohydrate)

Discussion and Conclusion

Games presented hereby could be useful for Biochemistry students to learn more easily some words from the glossaries of Biochemistry books [3, 4]. These games revealing words from codes will allow students to self-study these words and their structures. In the present work, the games have been classified according to the code used. Games revealing words from a known code have the added value for students of learning this code. Taking this into account, in Biochemistry the most useful game would be that one that uses the genetic code. With this code, the student learns the encoded words, but also the genetic code and the one-letter abbreviations of the amino acids, and perhaps also the names of the 20 protein amino acids. However, in this code two vowel (O and U) are missing, as well as 4 consonants (B, J, X, Z). This deficiency implies that not all words can be encoded. There are many biomolecules that end in –OSE (carbohydrates), which cannot be named with the genetic code because the O cannot be coded. One possibility would be to define new 3 letters codes that do not contain any letter of the four nitrogenous bases. Since there are 6 non-coded letters, 6 triads of letters could be used. One possibility is to use triads containing the same letter missing (OOO, BBB, JJJ, XXX, ZZZ). As U is one of the nitrogenous bases (uracil), UUU cannot be used, as this triad encodes F (phenylalanine). One possibility is to use the Stop codons (UAA, UAG or UGA) to encode the letter U.

Within the other codes, it may be interesting to use Morse or Braille and non-Latin letter codes, if the latter code uses the pronunciation of Latin letters. In this way, students can additionally learn these codes or the different alphabets. However, non-Latin alphabets do not always have a direct phonetic translation with Latin letters, so it could be a problem to apply these codes. Numerical codes, Latin letters and acrostic codes do not have the additional possibility to learn something different than biomolecules. As those codes are not international codes, translation will be useful to obtain the words, but learning the code would be nonsense. Regarding the acrostics, it is very laborious to prepare and provides few different results. Montessori method can be used in the Moodle environment, so that students have a set of games that they can use for their self-study. It will be possible to assess which games are preferred by each student and encourage students to be managers of their own training. The study using the glossaries of Biochemistry books is more arduous than to study using games. In fact, in the Chemistry degree at the University of Barcelona, Biology is taught in the first semester, whereas Biochemistry in the seventh semester. Biomolecule’s names could be forgotten by students and the perspective of using gamification to remember those names is better than to use glossaries. Since the students manage their own time, it is possible that they do not play the games if they do not receive a prize after resolution. In this sense, may be a good idea to solve in class a multiple-choice test applied to biomolecules, to reinforce the self-learning games.

International codes (genetic, Morse, and Braille) do not need to be displayed within the games. In addition, students can also learn these international codes. In the case of Biochemistry, the code that has the greatest interest is the genetic code, that allows students to learn the code, but also the one-letter abbreviation for protein`s amino acids, and maybe also the names and structures of amino acids. Numerical or Latin letter codes do not provide any other added value when translating, since the student should only focus on the translation and learn only the names of the biomolecules.

Notes

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