Development and use of puzzle and board games to complement the learning of biochemistry at university

Desenvolvimento e uso de jogos de quebra-cabeças e tabuleiro para complementar o aprendizado de Bioquímica no ensino superior

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Abstract
Biochemistry is an important area of knowledge for biology-based courses, although constantly the students face difficulties regarding the integral comprehension of issues involving biomolecules and metabolism. This scenario comprises an opportunity to adopt active methodologies such as playful classes. Thereby, this work aims to develop and apply a puzzle and a board game of Questions and Answers about biochemistry. These games were based on biomolecules and metabolism contents and were designed to offer a robust number of interactions possible between players to game and players to players. The games were named Bioquease Biomoléculas and Bioquease Metabolismo. They were applied to two classes of biochemistry (n=29), in which the students filled out survey forms to evaluate the games. The results showed that the questions of the game were related to what was learned in class, the difficulty was coherent with the one from the classes, the dynamics of the games were easy to comprehend, and the knowledge obtained was satisfactory, which comprise good alternatives to complement biochemistry classes.

Keywords: Biomolecules; Metabolism; Team-based learning.

Resumo
Bioquímica é uma importante área de conhecimento para cursos que envolvem biologia, entretanto constantemente os estudantes enfrentam dificuldades em relação à compreensão integral de assuntos que envolvem biomoléculas e metabolismo. Esse cenário confere uma oportunidade para adotar metodologias ativas, como jogos. Dessa forma, o presente trabalho objetiva o desenvolvimento e aplicação de um jogo de quebra-cabeça e de tabuleiro de perguntas e respostas sobre Bioquímica. Esses jogos foram baseados nos assuntos de biomoléculas e metabolismo e foram planejados para oferecer um número robusto de interações possíveis entre o jogo e os próprios jogadores. Os jogos foram nomeados como BioqEase Biomoléculas e BioqEase Metabolismo. Eles foram aplicados a duas turmas de Bioquímica (n=29), nas quais os estudantes preencharam um formulário para avaliar os jogos. Os resultados mostraram que as questões dos jogos estavam relacionadas com o que foi aprendido em sala, a dificuldade estava coerente com a dos jogos, a dinâmica dos jogos foi fácil de compreender e o conhecimento obtido foi satisfatório, compreendendo uma boa alternativa para complementar as aulas de Bioquímica.

Palavras-chave: Biomoléculas; Metabolismo; Aprendizado em grupo.
Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university

Record activity performed

<table>
<thead>
<tr>
<th><strong>Title</strong></th>
<th>Development and use of puzzle and board games to complement biochemistry subject matter learning at university</th>
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</thead>
<tbody>
<tr>
<td><strong>Target audience</strong></td>
<td>Undergraduate students enrolled in biochemistry subject matter</td>
</tr>
<tr>
<td><strong>Related disciplines</strong></td>
<td>Biology and chemistry</td>
</tr>
<tr>
<td><strong>Educational objectives</strong></td>
<td>To make students comprehend and study biochemistry contents through two games that can be applied in classes.</td>
</tr>
<tr>
<td><strong>Justification of use</strong></td>
<td>It’s known that biochemistry is a tough subject matter taught essentially by textbooks and slides, which can not approach all the student’s learning differences. Besides, playful methodologies, such as games, are good alternatives to approach different learning ways because of their visual contents, strategies’ scheme, and socialization and competition aspect. Thereafter, games may be good alternatives to teach and review biochemistry classes, making students more interested in the subject matter.</td>
</tr>
<tr>
<td><strong>Worked contents</strong></td>
<td>Structure, properties, and functions of amino acids, lipids, and carbohydrates; glycolysis, citric acid cycle, gluconeogenesis, electron transport chain, oxidative phosphorylation, fatty acid metabolism, fatty acid catabolism, synthesis of amino acids, regulation of metabolism, situations that affect metabolism.</td>
</tr>
<tr>
<td><strong>Estimated duration</strong></td>
<td>5 months for the conceptualization and design of the games, 1 month for their construction, and 2 hours for their application.</td>
</tr>
<tr>
<td><strong>Materials used</strong></td>
<td>For the puzzle game: 42 puzzle pieces, 1 mystery box, 1 die, 15 card of biomolecules, and 18 questionnaire leaflets. For the board game: 1 gameboard, 1 die, 6 questionnaire leaflets, 3 checkpoint cards, and 4 pieces of movement.</td>
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</tbody>
</table>
1 Introduction

Biochemistry is an important area of knowledge for biology-based courses at university since it presents an overview of the processes that take place within organelles, cells, and systems; and deploys a crucial foundation to scientific thinking and professional skills [1]. On the other hand, the teaching of biochemistry subject matters at university is challenging for most of the professors due to the necessity of turning complex ideas from articles and textbooks into something less abstract and easier to comprehend for the students [2]. Because of this, professors prefer teaching biochemistry by lecturing, which favors memorization of the theory [3]. Nonetheless, this kind of class, given generally by materials like textbooks, slides presentations, images, and videos makes the students simple receptors of information and does not stimulate active skills that turn the subject more interesting to them [4]. It is common for students to face difficulties regarding the integral comprehension of the issues involving biomolecules and metabolism, like the imagination of complex phenomena, the connection of events within the submicroscopic level, and the importance of some chunks in the system [5].

The subject matters of biochemistry offered by federal universities around Brazil are based on three main modules: biomolecules, metabolism, and molecular biology. The studies of biomolecules, like the drawing of structures of amino acids, carbohydrates, and lipids; along with the relation between chemical groups with their functions are important for a better understanding of biomolecules contents [6]. Furthermore, students often possess difficulties understanding key subjects regarding the metabolism subject, as the metabolism integration and the influences of parts of pathways over the whole system [7–8]. Besides, lectures based on oral and textbook methodologies harden the understanding of analogies and roles in biochemistry due to the necessity of linking several complex ideas in the text into a straightforward train of thought [9].

Students need to be presented to other alternatives to learn the contents of biochemistry, e.g. application of active learning methods to increase the retention of knowledge, preparation for different solving-problem challenges, and stimulation of their motivation [10-11].
To facilitate the understanding of contents taught in class, game-based lectures have the characteristic of offering a different perspective of the contents by modifying the visual, the animation, and even changing the role of the elements into something more fun for the students [12-13]. Moreover, game-based classes provide mechanisms that allow students to use different abilities, e.g. visual intelligence, articulation of strategies by the combination of kinds of knowledge, and by the need, from some games, to interact with other students [14]. This team-based aspect induces plural trains of thoughts by the promotion of discussion between players in order to achieve answers, and make students more engaged within the group to collaborate to the competition [14-16].

Therefore, the present article proposes to develop and evaluate the use of puzzle and board games on biomolecules and metabolism learning in biochemistry classes from the Federal University of Ceará (UFC) in Brazil.

2. Materials and Methods

2.1. Games development

2.1.1 Puzzle

The puzzle game, named BioqEase Biomoléculas, was developed based on the chemical structure of carbohydrates, amino acids, and fatty acids, which represent three important biomolecule classes. The selection of the biomolecules in each class was established according to their importance and role in biochemistry. The chemical structure of 5 carbohydrates, 5 amino acids, and 5 fatty acids were drawn on the program CorelDraw®. glucose, fructose, galactose, glucose-6-phosphate, and ribose constitute the carbohydrates; alanine, arginine, glutamate, glutamine, and tyrosine, the amino acids; and arachidonic acid, palmitic acid, diacylglycerol, octadecanoic acid, and 9,12-octadecadienoic acid (omega-6) constitute the fatty acids.

The puzzle lines of the biomolecules were designed to highlight relevant chemical groups, such as the hydroxyls of the carbohydrates; carboxyl, amino and radical (R) groups in amino acids; and acyl groups in lipids (Figure 1). Each biomolecule was divided from a range of 5 to 7 pieces each, depending on its chemical structure size.
Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university

Figure 1. Representation of every piece present in puzzle game BioqEase Biomoléculas. Each biomolecule possesses a color to distinguish it from others

The game materials consist of puzzle pieces handcrafted by printing the images of the biomolecules on A4 paper that was glued on a wooden-like paper (~4mm of thickness) to make the puzzle pieces. Furthermore, there are 6 questionnaires [Appendix A] of questions printed on A4 paper and folded in the format of leaflets. Each questionnaire has 7 questions with answers from the subjects of biomolecules (Frame 1A). These questions were obtained from the main reference used in Biochemistry classes across Brazil [17]. The questions vary in style, having multiple choice and short answer questions; and in difficulty to be answered, which is indicated by a colored circle beside the question text, being green for easy, yellow for medium, and red for hard questions. There are 21 easy, 70 medium, and 35 hard questions, as showed on Appendix A. For the difficulty, it was taken into consideration the knowledge necessary within the biochemistry course to answer correctly the questions. Based on this, it was subjectively attributed one of the three difficulties on each question. Bellow the questions, the correct answer is displayed. The game contains a mystery box either, made of a conical cup of 1 liter with a cloth wrapped on the upper part of the cup to hide the puzzle pieces inside and contains an elastic hole that permits to sink the hand to reach the puzzle pieces to pull them out of it. Besides, there is a die to roll a number from 1 to 6 to select one of the six questionnaires.
Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university

### 2.1.2. Board

The game is centered on a board (70 by 55 cm), named BioqEase *Metabolismo*, representing the main metabolism pathways studied on the subject matters of biochemistry (Figure 2). The board was handcrafted by printing the full gameboard on a thick wooden-like paper (~6mm) and covered by adhesive paper to convey a smooth texture. This game contains 6 questionnaires [Appendix C], each of them having 20 questions with answers from the subjects of metabolism (Frame 1B). The style of the questions comprises short answer and multiple-choice questions, like the BioqEase *Biomoléculas* game, having 23 easy, 68 medium, and 29 hard questions. The questions were also based on the contents of Lehninger’s reference [17]. There is a die to roll numbers from 1 to 6 to pick up one of the six questionnaires. Other featured materials are three cards of checkpoints: the first for the beginning, at the first space, and two for the respective checkpoint spaces (Figure 3). These checkpoint cards explain the pathway flux taken in the gameboard, contextualizing people's attitudes, such as alimentation, sleeping, and exercise practicing with their respective metabolic outcomes.

### 2.2 Application and Evaluation of the Games by Students

We applied the games on November 19, 2019, and November 22, 2019, to two classes from the courses of zootechny and biology, respectively, at the UFC. The students were enrolled in a biochemistry subject matter (n=29). The 29 students were studying the biochemistry matter for the first time and the period of the game application was in the
Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university

penultimate week before the final exam; therefore, the students had already studied the subjects of the games.

The first part of the application consisted of the students playing both games, beginning with BioqEase *Biomoléculas*. The players were divided into three teams to play both games, in which the three teams of zootechny class (n=14) were comprised of two groups with 5 and one with 4 players; and the three teams of biology class (n=15) were divided to have 5 players each.

After the matches, every student received two survey forms for each game with the same questions in order to evaluate the games regarding three aspects: the content, dynamics of the game, and the learning obtained from the game (Table 1). The questions of the form were based on a Likert Scale ranging from 1 to 5 in the format of agreement and disagreement. The students filled out the forms without revealing their names.

<table>
<thead>
<tr>
<th>Questions on the forms</th>
<th>Options of answers for each question</th>
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<tbody>
<tr>
<td>About the content of the game</td>
<td>1. Strongly disagree</td>
</tr>
<tr>
<td>The questions contained contents learned in class</td>
<td>2. Disagree</td>
</tr>
<tr>
<td>The questions’ difficulty was according to the level of the contents of the classes</td>
<td>3. Neutral</td>
</tr>
<tr>
<td>Was hard for you to answer most of the questions</td>
<td>4. Agree</td>
</tr>
<tr>
<td>About the game functioning</td>
<td>5. Totally disagree</td>
</tr>
<tr>
<td>The game was clear and easy to understand</td>
<td></td>
</tr>
<tr>
<td>The style of questions was adequate</td>
<td></td>
</tr>
<tr>
<td>About the learning obtaining</td>
<td></td>
</tr>
<tr>
<td>The games contributed to your learning of biochemistry</td>
<td></td>
</tr>
<tr>
<td>The team interactions facilitated the learning of the contents</td>
<td></td>
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Every question was explained to the students about what is necessary to take into consideration to answer correctly and unbiasedly. The form results were filled on a Google Forms file to organize the data; the statistics and graphs of each answer were generated by the program Excel.
3 Results and Discussions

3.1 Games Development

3.1.1 Puzzle

It’s shown in Figure 1 all the biomolecules’ drawings and their respective puzzle lines focusing on chemical groups that have a biochemical role, even the puzzles themselves not being asymmetric though. The pieces’ shapes were designed to not affect the molecular structure drawing and to enable the single pieces to assemble in more than one biomolecule of the same class. Then, in the game, we made just one single copy of each biomolecule, and there is no overlay since each team plays with different biomolecule classes.

About the game rules, it starts with a prior division of the students into 2 to 3 teams, and it is necessary to roll a die to draw which biomolecule the teams will play with. Thereafter, each team chooses a number from 1 to 5 equivalent to the biomolecules of the drawn class. Then the teams receive a card containing a chemical structure of the biomolecule’s picture and information about the chemical and biochemical characteristics, roles, and curiosities, as a biomolecule profile for the students to review [Appendix B]. The information in the cards does not overlay the text or answers to the questions. To start the game is necessary to set up who will be the mediator, whose role is to read the question text, its difficulty and to tell if the team has answered it correctly.

Thus, the game begins with the first team rolling the die to draw one of the 6 questionnaires, which all contain questions specific to the biomolecule chosen [Appendix A]. Then, the team needs to choose a number from 1 to 7 respective to the question in the questionnaire and answer it within 1 minute. The students can chat within the group and discuss ideas to come up with an answer. If it is correct, the team unboxes 1, 3, or 5 pieces if the question difficulty is easy, medium, or hard, respectively out of the mystery box until taking a piece that matches on the puzzle, stopping unboxing then. Therefore, if the team does not unbox a piece that matches the puzzle, the piece is returned to the mystery box. After the play, the next team executes the same step by step. Wins the game the team that first assembles the puzzle of its biomolecule.

3.1.2 Board

The gameboard was designed to represent information about the contents of metabolism, which shows a perspective inside a cell, beginning at the first reaction of glycoly-
Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university

...sis and flowing all the way to the electron transport chain (Figure 2).

Figure 2. Representation of the gameboard that contains all the 39 spaces necessary to jump to achieve the final space (CTE, indicated by a yellow arrow). The visual elements simulate the perspective within a cell, where on the top has the cell membrane and the double-strand that crosses partitioning the gameboard comprises the mitochondrial membrane. The gameboard shows different compartments, like the cytoplasm, intermembrane space, and lumen. Some reactions’ products were omitted to facilitate the game dynamics. Every pathway contains a dotted-line box of general information about that metabolism portion and its role.
Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university

The name and chemical structure of each reaction intermediate are labeled along the pathways to facilitate the memorization of the student and it contains the increments and subtractions of the energy currencies, like adenosine triphosphate (ATP), the coenzymes nicotinamide adenine dinucleotide phosphate oxidized and reduced (NADP+/NADPH), and flavin adenine dinucleotide oxidized, and reduced FADP/FADH2. Besides, the gameboard presents a systematic view of all the pathways and the integrations that can happen between them, e.g., the metabolism rate flowing from the Acetyl-CoA towards the Malonyl-CoA to enter in the Fatty Acid Biosynthesis under a scenario of excess of energy.

Before the game starts, it is necessary to set up to 4 teams to play the game, including a person who will be the mediator. Then the game starts with the first team rolling the die from 1 to 6 corresponding to a questionnaire. Thereafter, the team chooses a number from 1 to 20 that matches a question on the questionnaire and answers it in 1 minute. The mediator reads the question and tells if the level of the question is easy, medium, or hard, and, if the answer is correct, the team jumps 2, 4, or 6 spaces, respectively. Every team ought to stop the jumps on the checkpoint spaces regardless of the number drawn on the die, and each team receives the cards respective to the checkpoint to contextualize the path taken in the game (Figure 3). The first team to first jump from the first space (Glucose) until the last one, wins the game.

![Figure 3. The checkpoint cards that are delivered to the teams after reaching the respective checkpoint spaces](image)

3.2 Application and Evaluation of the Games by the Students

The analysis of the data obtained by the survey provided an overall assessment of the effectiveness and potentials of both games. It is demonstrated in figure 4 the perception of the students about the correlation between the contents learned in the lectures of biochemistry and the contents of the games. The high percentage for the first question’s
answer demonstrates the accordance between the contents of the games and the lectures (Figure 5A). Although, the aspects evaluated about the difficulty concerning the lectures’ level (Figure 5B) and the difficulty based on the student’s knowledge (Figure 5C) exhibited a higher density of answers over the neutral zone of the graphic. This result indicates the questions were challenging for some students, but as it does not exceed the level of the lectures though, it may assist students on their biochemistry exams.

Figure 4. Evaluation of the contents of the puzzle (BioqEase Biomoléculas) and board (BioqEase Metabolismo) games and their difficulty by students of biochemistry matter from UFC. A: The questions contained contents learned in class; B: The questions’ difficulty was according to the level of the contents of the classes and C: It was hard for you to answer most of the questions

It is shown in figure 5 the results about the aspect of dynamics of the game. For the first question, 82,75% and 100% of students answered that BioqEase Biomoléculas and BioqEase Metabolismo, respectively, were easy to comprehend and all the rules and the steps demanded to play the game were not complicated. The second question evaluated the convenience of the question styles of both games, in which 65,15% and 93,1% of the students totally agreed that they were suitable for the learning acquisition. One detail worth to be considered is that some multiple-choice questions have a long text, including its options. At those questions, the students frequently requested to repeat the reading to understand in detail. Due to the fact that some questions need a text, the mediator has to read out loud slowly and clearly, so the student can keep their thoughts up with the reading.

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Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university

The last aspect evaluated takes into consideration the learning acquisition provided by the game. It is shown in figure 6 the high percentage of total agreement in favor of the games, comprising 72.41% and 82.75% of total agreement on BioqEase Biomoléculas and BioqEase Metabolismo to contribute to their learning of biochemistry. Besides, 89.65% and 86.2% of the students totally agreed that the group interactions facilitated the obtaining of learning. This result shows that team-based learning carries out a key aspect of the experience, especially because each player shared their knowledge with the whole team to reach correct answers.

Figure 6. Impressions of the students about the obtention of knowledge and contribution for the learning of biochemistry by playing the puzzle (BioqEase Biomoléculas) and board (BioqEase Metabolismo) games. A: The games contributed to your learning of biochemistry and B: The team interactions facilitated the learning of the contents
The purpose of this work was to create games that apply contents from the textbook bibliography taught in class and to allow different mechanisms to stimulate the knowledge from class in a visually attractive, interactive, and team-based way. Moreover, the games were planned to involve elements of competition related to Questions and Answers (Q&A) of the subjects of biochemistry, simulating a test that may assist students on their exams. Based on this, the questions show contents that may be for biochemistry exams, based on Lehninger’s reference [17].

Each game was designed to incorporate the maximum of strategies that lead to an integral understanding of the contents and to apply multiple forms of active interactions to consider students’ learning differences. What defines the success of the teams to win the game is mainly the knowledge from every participant to answer correctly the questions. All the other forms of active interactions and visual contents mean to assist students to remember and associate the knowledge learned in the classes.

During the application of the games, the students were delighted by the visual contents and the depths of details. While playing BioqEase Biomoléculas, the students were studying not only by the questions and answers but reviewing the information of other biomolecule’s cards received either. In BioqEase Metabolismo, whereas one team was occupied rolling the die and thinking about the answers, the other teams were analyzing the pathways, the chemical structure of the intermediates, and the energy balance of the pathways, information provided on the gameboard. These actions proved the game was not only centered on reviewing the knowledge by answering questions.

We did not evaluate the role of visual contents on the learning process from the chemical structure of the biomolecules and gameboard. Although it certainly played a key role in facilitating their acceptance of the game and enjoyability, as it is known that the efficiency of articulating representations, like images, tools (e.g. pieces and apparatus), and activities (e.g. actions and methods) are crucial elements to enhance students’ discourses and, consequently, assist to come up with clever ideas for exams [18]. Moreover, showing images of biomolecules with associations between structure and function is a reliable method to reach visual literacy for students [19].
BioqEase *Biomoléculas* is an innovative jigsaw puzzle game that aligns the visual picture of chemical structures of biomolecules and their profile with a Q&A focused on biochemistry exam assistance. We did not see these characteristics in any other game that proposes to assist students in biochemistry classes. Nevertheless, other puzzle games prove to contribute to the learning of biochemistry. Foldit is an online multiplayer platform that simulates protein folding structures similar to a puzzle in a collaborative environment that has been used as a successful tool to teach protein structures in classes of biochemistry, having a great acceptance among students [20–22]. The main difference between Foldit and BioqEase *Biomoléculas* is the subject focus. While Foldit is centered on protein assembly and protein structures, BioqEase *Biomoléculas* attempts to offer an overview of biomolecules from the chemical structure to the biochemical characteristics. O’Halloran [23] developed a puzzle game that teaches students molecular structures based on templates that must be fit with sticky notes of atoms with their bonds. The game has a great playful learning characteristic, being similar to BioqEase *Biomoléculas* since it stimulates the memorization of the chemical structure during the match.

About board games to teach metabolism to students, a few games have been made in biochemistry classes. Tyler [24] developed a board game called Race to Glucose, which has cards to elucidate some subjects of metabolism, involving questions from the theme, and with condition and regulator cards that drive to biochemical states. It also contains chemical structures and names labeled along the pathways, having more from these than BioqEase *Metabolismo*. Even though, Tyler’s gameboard did not present a board such as this one, because we focused on several visual details, such as the placement of particles in a cell, the presence of mitochondrial bilayer structure with the electron transport chain proteins embedded in it. Bioquim4x is a board game centered in the advance of each player throughout the spaces until reaching the final by answering questions in cards about contents that prepare students for exams [25]. Both games received good acceptance by the students and are useful alternatives to biochemistry classes. Thus, according to our literature research, what makes BioqEase *Metabolismo* innovative is the integration of several elements in just one game, like detailed visual content, summaries over the gameboard, interaction within the teams, and questionnaires that simulate exams. This plural characteristic of the game tackles different methods of learning and permits students with divergent skills to improve their biochemistry knowledge.
4. Final considerations

This work presented successfully two new games based on a puzzle and board as playful methodologies to incentive the student’s motivation for biochemistry classes by the combination of visual elements, description, summary of several contents, team-based learning, and questions simulating exams. The positive evaluation of both games by the students demonstrates that the games are a good alternative for biochemistry studies and offer a lighter way to study this difficult subject matter. The dynamicity of the games innovates in biochemistry teaching. Therefore, the games are a valid choice for biochemistry professors to teach biomolecules and metabolism issues of biochemistry as a complementary tool to stimulate students, being possible to apply it in a reviewing class or in extra moments, such as tutoring.

References


Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university


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We would like to thank all the students that participated in the game application and collaborate to get this work done.
Educational innovations: Development and use of puzzle and board games to complement the learning of biochemistry at university

Appendix A. Example of questionnaire of the game BioqEase Biomoléculas

1. Caracterize quimicamente um aminoácido. ●
R: Um monômero de 3 carbonos que contém um grupamento amina e um grupamento carbonil, além de um hidrogénio e um grupo lateral específico.

2. Qual o único aminoácido proteico que não tem um carbono íque é um centro quiral? ●
R: Glicina

3. Qual dos seguintes grupos contem pelo menos um dos vinte aminoácidos proteicos? ●
A) Grupo R polar e aromático.
B) Grupo R apolar e carregado negativamente.
C) Grupo R carregado negativamente.
R: C

4. O que são aminoácidos essenciais? ●
R: Aminoácidos que não são sintetizados pelo corpo humano.

5. Um aminoácido com um grupo lateral ionizável, seja positiva ou negativamente, tem quantos pKa? ●
A) 1.
B) 2.
C) 3.
D) 4.
R: C

6. Um tripeptídeo tem 3 aminoácidos, assim como um tetrapeptídeo tem: ●
R: quatro aminoácidos.

7. Cite dois objetivos de uma titulação de aminoácido? ●
R: Determinar pKa/ Concentração do aminoácido/ Determinação do pH/ Determinação da zona de tamponamento.

Appendix B. Example of card of the biomolecule profile and correct assemble of the respective puzzle

**Informações da biomolécula**

Nome da biomolécula/Nome Sistemático: Ácido palmítico/Ácido n-hexadecanoico.

Função bioquímica:

Produtos principais de biossíntese dos ácidos grasos, a partir dos quais outros ácidos grasos são gerados.

**Observações da biomolécula:**

Ácido graxo de 16 carbonos. Não contém insaturação.
Appendix C  Example of questionnaire of the game BioqEase Metabolismo

1: Não é uma função da via de biossíntese de lipídios: - R: D.  ●
   A) Produção de fosfolípidos de membrana para a divisão celular.
   B) Produção de eicosanoides.
   C) Produção de triacilglicerol de armazenamento.
   D) Produção de proteínas conjugadas à lipídios.
2: Qual a enzima responsável por produzir NADH na glicólise?  - R: Gliceraldeído 3-fosfato deidrogenase ou G3PD.  ●
3: Qual das seguintes moléculas não está presente nos complexos de proteínas constituintes da cadeia transportadora de elétrons? - R: D.  ●
   A) Citoconos.
   B) Proteínas FeS.
   C) Ubiquinonas.
   D) Proteínas Fe-N.
4: Na fase preparatória da glicólise ocorre a adição de grupos fosfatos ativados do ATP. Quantas moléculas de ATP são necessárias nessa fase, considerando uma molécula de glicose? - R: 2.  ●
6: O piruvato deve ser convertido a lactato para que o NADH seja convertido em NAD+ e assim possa manter a glicólise. Verdadeiro ou falso? - R: Verdadeiro.  ●
8: Anaerobismo são reações de catabolismo de moléculas, as quais envolvem produção de energia nesse processo. Verdadeiro ou falso? - R: Falso.  ●
10: Um Inibidor Competitivo:  R: A.
   A) Compete pelo sítio ativo da enzima.
   B) Compete pelo complexo Enzima-Substrato.
   C) Compete pelo sítio ativo da enzima e pelo Complexo Enzima-Substrato.
11: Qual o nome da enzima que catalisa a fosforilação do ADP, formando ATP?  - R: ATP sintase.  ●
12: Qual das seguintes moléculas é um regulador positivo do ciclo do ácido cítrico?  - R: C.  ●
   A) NADH.
   B) ATP.
   C) Ca2+.
13: Qual das substâncias abaixo é precursora de uma coenzima que participa da atividade da enzima piruvato deidrogenase? - R: A.  ●
   A) Riboflavina.
   B) Pantotenato.
   C) Biotina.
14: Em qual via do metabolismo o NADH e o FADH2 são oxidados?  - R: Cadeia Transportadora de Eletrons.  ●
15: Qual das seguintes opções é um regulador positivo da fosfofrutocinase da glicólise?  - R: C.  ●
   A) ATP.
   B) 1,3-bifosfoglicerato.
   C) Frutose-2,6-bifosfato.
16: O ciclo do ácido cítrico gera quantos mol de NADH?  - R: 3.  ●
   A) 1.
   B) 2.
   C) 3.
   D) 4.
17: é uma função da via das pentoses-fosfato?  - R: B.  ●
   A) Produzir nucleotídeos.
   B) Produzir ribose-5-fosfato, um precursor dos nucleotídeos.
   C) Produzir pentoses, tais como arabinose e xilose.
   D) Oxidar pentoses, tais como arabinose e xilose.
18: São produzidos diretamente, uma série de quatro reações da "oxidação": - R: A.  ●
   A) 1 NADH e 1 FADH2.
   B) 2 NADH.
   C) 2FADH2.
   D) 1 NADH e 1 ATP.
20: É função dos corpos cetônicos?  - R: C.
   A) Desinfetar infecções intracelulares.
   B) Servir de estrutura para purinas e pirimidinas dos ácidos nucleicos.
   C) Servir de combustível para órgãos e tecidos que sofrem de carência de energia.
   D) Inmobilizar toxinas presentes no plasma sanguíneo.