BioQuest: Gamified software for teaching molecular biology

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Abstract

Science teaching in basic education aims to provide content for individuals who can handle with new information and are able to understand, question and position themselves before ethical debates related to biotechnology and molecular biology. However, the information flow generated in the molecular biology field is not accompanied by the dissemination of scientific information into the school environment, nor is it incorporated into the teaching knowledge on a continuous basis. In addition, the teaching of molecular biology and its related concepts, which involves great abstraction capacity on the part of students, requires the elaboration and use of specific didactic resources. Thus, this work aims to present the gamified software BioQuest and its usability and interface evaluation made by 131 Brazilian high school students from the São Paulo State public school system in São Carlos region. The data show that there is no significant difference in the game evaluation made by students with previous experience with games and those without the habit of playing, except when it comes to understanding the commands proposed by the game. This implies that students with previous experience in games have greater ease in using this teaching resource. Regarding the impact on their learning, the data show that students who interacted with the game performed better on conceptual issues related to Molecular Biology when compared to students who did not. Specifically, the questions related to game phases that contained gamification elements of the narrative and extrinsic motivation types, correlated with better grades obtained by the students. The practical experience of BioQuest proposed for high school students allowed to observe a significant improvement in the quality of teaching that can contribute to became a reference in this area.

Keywords: teaching; molecular biology; gamified software.

1. Introduction

The understandings of concepts related to molecular biology and biotechnology are presented to the students in the last years of elementary school when they have the first contact with terms such as cell, DNA, proteins and biotechnological use of microorganisms. This is important to relate and understand more complex concepts and processes, in addition to enabling analysis and decision making on issues involving science, technology and society. Therefore, it is fundamental the mastery of these concepts by teachers and students for a meaningful learning.

It is observed in literature, publications that highlight challenges in teaching molecular biology.

Cirne (2013) showed that few studies address the learning difficulties of biology content studied in elementary school, especially basic notions of genetics and cell biology. Also, in a research conducted with 8th grade students of a public school in the state of Rio Grande do Norte (Brazil), it was detected their difficulty about concepts of gene, DNA and chromosome.

Kazitoris and Neto (2015) point out, in a study that investigated alternative conceptions (of the evaluated subjects) in biology, documented in dissertations and theses from 1972 to 2012, that the themes of heredity, sexual reproduction, transgenics and DNA were widely explored in the considered works. The previous conceptions show the difficulty in learning scientific definitions such as: Mendel's Law, chromosomal theory, mitosis, meiosis and the location of genetic material. Furthermore, they do not understand cell as a morphophysiological unit, they cansuppose that the genetic material is restricted to mammals and is present only in blood. They do not conceive the existence of other types of cells, neither perceive the DNA as part of all cells, and the relation between DNA and transgenics or DNA and phenotypic characteristics.

In a work that discuss the teaching resources adopted by biology and science teachers in public schools, Moura and collaborators (2013) state that the use of the text book as a unique teaching tool, with abstract and superficial contents, it is also a relevant problem that increases the gap between reality and the knowledge obtained in school. Thus, being or not a unique teaching instrument, it is necessary to evaluate how the New Biology is inserted in high school textbooks.

Xavier, Freire and Moraes (2006) analyzed, in 18 text books, the presence of themes associated to the New Biology: transgenics, Genome Project, mammalian cloning, stem cells, paternity testing, genetic variability, recombinant DNA, hybridization, sequencing, restriction enzymes, plasmids, introns and exons, electrophoresis and PCR technique. From this analysis, the following points are highlighted:

i. Themes such as sequencing and electrophoresis are mentioned in some of the works analyzed, without containing any explanation, sequencing being the most impaired, quoted only once;

ii. The results of this research indicate that the updates in the textbooks are the same made in 1997 by Amaral and Megid-Neto (1997) apud Xavier et al. (2006);

iii. Regarding the illustrations on the researched topics, it is important to point out that some topics that were mentioned have no illustrations whatsoever.

The above authors ratify that the Modern Biology approach presented in textbooks does not contribute to the student becoming a critical citizen.

At the national level these and other works in the area (Cirne, 2013; Fontes, Chapani & Souza, 2013; Tauceda & Pino, 2010; Justina & Ripel, 2003) indicate that the teaching of Molecular Biology and its

underlying concepts encounter many obstacles. Such concepts should be studied in depth in the field of research in teaching molecular biology and related areas such as biochemistry and genetics.

Globally, research has shown that the use of experimentation (Ben-Nun & Yarden, 2009) and diversified resources such as games can improve the quality of learning subjects that require abstraction of concepts as well as making teaching more motivating. (Severo & Kasseboehmer, 2017; Spiegel et al. 2008; Cardoso et al., 2008).

According to Mascarenhas et al. (2016) the exploration of the playful aspect of different practical activities is shown to be an effective tool, as it promotes a significant improvement in the quality of teaching and learning and gives the opportunity for students to actively participate in classes, asking questions and solving proposed problems.

The use of information and communication technologies, such as applications, animations, videos, educational games and / or gamified software (Marbach-Ad, Rotbain & Stavy, 2008; Cheng, Lin, & She, 2015). Games and applications (among others) can support learning, enabling the development of knowledge in a fun and interactive way, increasing the motivation of students (Carvalho & Guimarães, 2016).

Although Kim, Park and Baek (2009) state that games can improve the ability of students to solve social problems, it must be considered that acceptance by students is not always guaranteed. In the meantime, it is necessary to observe their experience and their immersion and how they access and use the game, as pointed out by Bourgonjon and collaborators (2010).

Regarding computer games aimed at teaching Molecular Biology and related subjects, the literature presents the games Hangman (Pennington, Sears & Clegg, 2014), Imunne Attack (Stegman, 2014) and MolWorlds (Gauthier & Jenkinson, 2017).

Hangman is a puzzle that allows the student to practice the design of the structures of amino acids and to relate them to their representation of 1 letter and it is aimed at college students. (Pennington, Sears & Clegg, 2014).

Immune Attack (Stegman, 2014) is a third-person game in which the player must activate specific proteins to trigger specific behaviors of various white blood cells. The players travel throughout the veins as micro-robots and nano-robots passing through the connective tissue and reaching the surface of the white blood cells where they receive different instructions to activate certain proteins and they have to solve failures in the patient immune system.

According to the author, there is no explanation of what a protein is, however the students who used the mentioned game were able to obtain a higher score in a questionnaire containing Molecular Biology questions compared to those who did not play it. This reference shows that there are still many possibilities to be explored in the scope of serious games for the teaching of molecular biology, focused on basic education.

MolWorlds: third-person game that allows the students to experience cellular processes such as (translation of RNA among other processes) where they can manipulate variables such as temperature and molecular concentration for example. (Gauthier & Jenkinson, 2017).

Considering all the previously mentioned, this work aims to analyze the learning of concepts related to Molecular Biology using a gamified software / educational game called BioQuest as a tool, investigating

whether the game influences the learning of these concepts, when compared to the traditional approach used in basic education schools. Also, if a prior experience in games can influence the use of students and a better performance of this tool.

2. Development

Author and teaching team opened firstly a continuous training course in self-learning platform applied for teachers from the state school system, in São Carlos-SP, during the month of August in 2017, with the participation of 14 teachers. During this training course, it was possible, through a questionnaire and interaction with participants, to get to know the profile of the science and biology teachers from basic education and to gather data such as: training, professional profile and pedagogical practices for teaching concepts of molecular biology.

These data supported the creation of the gamified software Bioquest, using the games development platform GameMaker. The game development can be divided into two major stages:

1) Conception and Game Design stage in which it is decided which elements of gamification and mechanics will be inserted in the games, as well as the contents / skills and objectives of the game.

2) Coding and prototyping: step in which coding is done into the chosen computer language, in which the arts, sound effects and prototypes are generated for testing. This second stage was carried out in collaboration with an artist and independent game developer Gabriel Lima.

The purpose of the software is to make students understand the strategies involved in Molecular Cloning and to understand the processes in the production of a recombinant protein. In the software, we chose the model of human insulin, however, at the end of the exploration, it is expected that the student will be able to extrapolate that model, applying it to the production of other recombinant proteins.

When accessing the software, after the opening screen is displayed, as shown in figure 1A, a path to be taken by the student marked by nine phases / stations is shown on the screen through which can be navigated freely without blocking or requiring the student to reach a minimum score by pressing the buttons 1 to 9 as shown in figure 1B. This allows the exploration of the tool to take place in more than one class, considering that currently the classes are 45 minutes long and that students have two biology classes per week. Blocking the phases could make their use unviable.

In order to validate such material, classroom interventions were carried out, a total of 131 evaluations made by students on the interface, interactivity, mechanics and relevant aspects of the game, as well as the impact of using the software on the responses to a conceptual questionnaire, answered by 26 students.

2.1 The software

The software is mean of promoting teaching. It takes advantage of information technology to generate learning platform to support teachers teaching.

The narrative begins by proposing to the player the mission of knowing and assisting in the insulin production process. The home screen of the software allows them to navigate freely through its phases without blocking or needing to reach a minimum score to pass the level. It is recommended that browsing through BioQuest is not done in a single class.

Although navigation is free, it is recommended that driving and progressing in the software start with the exploration of phase 1 and finish in phase 9. This order will lead the student to the most known and used molecular biology techniques for the creation of a recombinant bacterium, capable of synthesizing the human protein, insulin.

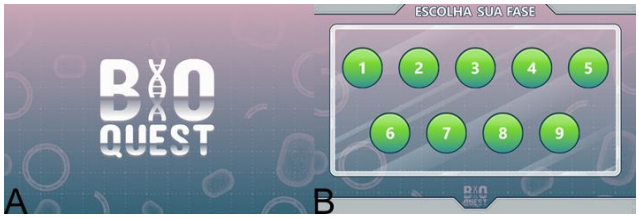

Figure 1. (A) Software opening screen; (B) Navigation screen

Game Phases

- Phase1: introduces to the user the Molecular Biology technique known as Polymerase Chain Reaction (PCR).
- Phase 2: the DNA sample amplified by the PCR was not labeled correctly and it was swapped with others stored in the same freezer. The user can interact with the software by recognizing enzyme restriction sites EcoRI in these DNA samples and cleaving them.
- Phase 3: the samples are submitted to an agarose gel electrophoresis technique and by doing so it is possible to determine through comparison which sample contains the amplified fragment of insulin.
- Phase 4: the player assumes the role of the restriction enzyme in order to cleave the plasmids.
- Phase 5: amplified fragments of insulin will be inserted in the plasmids cleaved in the previous phase.
- Phase 6: transformation of bacterial cells with the recombinant plasmids created in the previous steps.
- Phase 7: selection of which bacteria have actually been transformed.
- Phase 8: possibility to track the expression of the insulin protein in the bacterial cell.
- Phase 9: the player can test his knowledge in a challenging quiz.

3. Intervention and data collection

The invitation for the teachers voluntary participation in this research was made through a partnership with the Board of Education in São Carlos, a public agency with the function to administratively and pedagogically manage public schools in a given region, submitting themselves to the Secretary of Education of the São Paulo State.

The invitation was made through electronic contact with the 32 School Units under the management of this board, containing the main research information, alongside the Informed Consent Form. It was disclosed by the coordinating teachers during the collective pedagogical work class, a weekly meeting concerning the teaching workload, whose primary goal is the teachers continuing education provided by the school, Board of Education or the Secretary of Education of the São Paulo State. 6 out of 52 teachers with assigned Biology classes across the state education network of DER- São Carlos expressed interest in participating in the research, 4 from school unit 1, 1 from school unit 2 and 1 from school unit 3.

Then, a training meeting was held with interested teachers, in their school units, to instruct about the

information contained in the software and how to use it. The requirement for the intervention to take place in the classroom was that the teacher had already worked on the concepts related to Molecular Biology in the classroom. According to the Official Curriculum of the State of São Paulo (2012), such content can be found in the third and fourth bimester of the 2nd grade of high school. All interventions were carried out throughout November 2019.

Each teacher used the BioQuest software for two 50-minutes classes, in the computer room of their respective school units (Figure 2). They received explanations referring to the conceptual classes of each subject in the classroom and then asked each student to complete a printed assessment of the software.

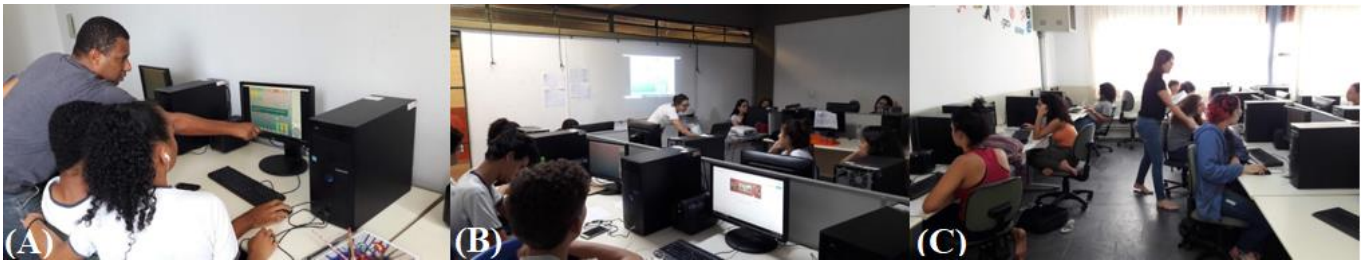

Figure 2. Use of the BioQuest Software at school 1 (A), 2 (B) and 3 (C) during the month of November in 2019.

The evaluation of the software was carried out through a post-test questionnaire that used the semantic differential (Jappur, 2014), as shown in Table 1, to gather information about the design of the software, controls, screens, mechanics, usability and questions related to its interaction with classmates, teacher and the BioQuest tool during class. The public had contact with content related to Molecular Biology.

Table 1. Questions used to assess the perception of students using the game.

Statements related to the opinion of students after using the BioQuest software.		Selection of a value between -3 and 3 that best represents the opinion of students regarding the statements.
S1	The *design* of the game is attractive (screens or objects, movement of objects, etc.).	Ugly -3 -2 -1 0 +1 +2 + 3 Attractive
S2	The design helped me to keep an eye on the game.	Irritating -3 -2 -1 0 +1 +2 + 3 Nice
S3	The game content is relevant to my learning.	Irrelevant -3 -2 -1 0 +1 +2 + 3 Relevant
S4	It was easier to understand the game.	Difficult -3 -2 -1 0 +1 +2 + 3 Easy
S5	I'm happy because I'm going to use things I learned from the game at my residence.	Dissatisfied -3 -2 -1 0 +1 +2 + 3 Satisfied
S6	I didn't notice the time passing while playing, when I saw it, the game was over.	Uninteresting -3 -2 -1 0 +1 +2 + 3 Interesting
S7	I was able to interact with other people during the game.	Off -3 -2 -1 0 +1 +2 + 3 Interact
S8	This game is challenging for me, the tasks are difficult and make me think	Weak -3 -2 -1 0 +1 +2 + 3 Challenger

S9	I had fun with the game.	Boring -3 -2 -1 0 +1 +2 + 3 Fun
S10	I managed to get to the end of the game (results).	I failed it -3 -2 -1 0 +1 +2 + 3 I got it
S11	How do you evaluate your performance obtained in the game.	Terrible -3 -2 -1 0 +1 +2 + 3 Great
S12	The controls for performing actions in the game responded well	Uncontrollable -3 -2 -1 0 +1 +2 + 3 Controllable
S13	It is easy to learn to use the interface (screens) and controls of the game.	Complicated -3 -2 -1 0 +1 +2 + 3 Simple

To analyze the impact of the game on the learning of students, a questionnaire was applied containing ten conceptual questions for both students who used the BioQuest software and for students who had not interacted with the game. (See questions used to assess the impact of the game on learning concepts related to Molecular Biology in Appendix 1).

4. Results and Discussion

Nine interventions were carried out with students of the 2nd grade of high school, in three state schools of São Carlos area, State of São Paulo, a total of 131 evaluated subjects, aged between 16 to 18 years.

The responses to the questionnaires were classified into two groups: group 1 - composed of 32 students (24.4%) who have no experience / consume games, and group 2: composed of 99 students (75.6%) who reported having experience / consume games.

On average, the students consume games 5 times a week, spending 3 hours and 20 minutes a day.

The graphs shown in the following image were obtained from the responses of students (Figure 3).

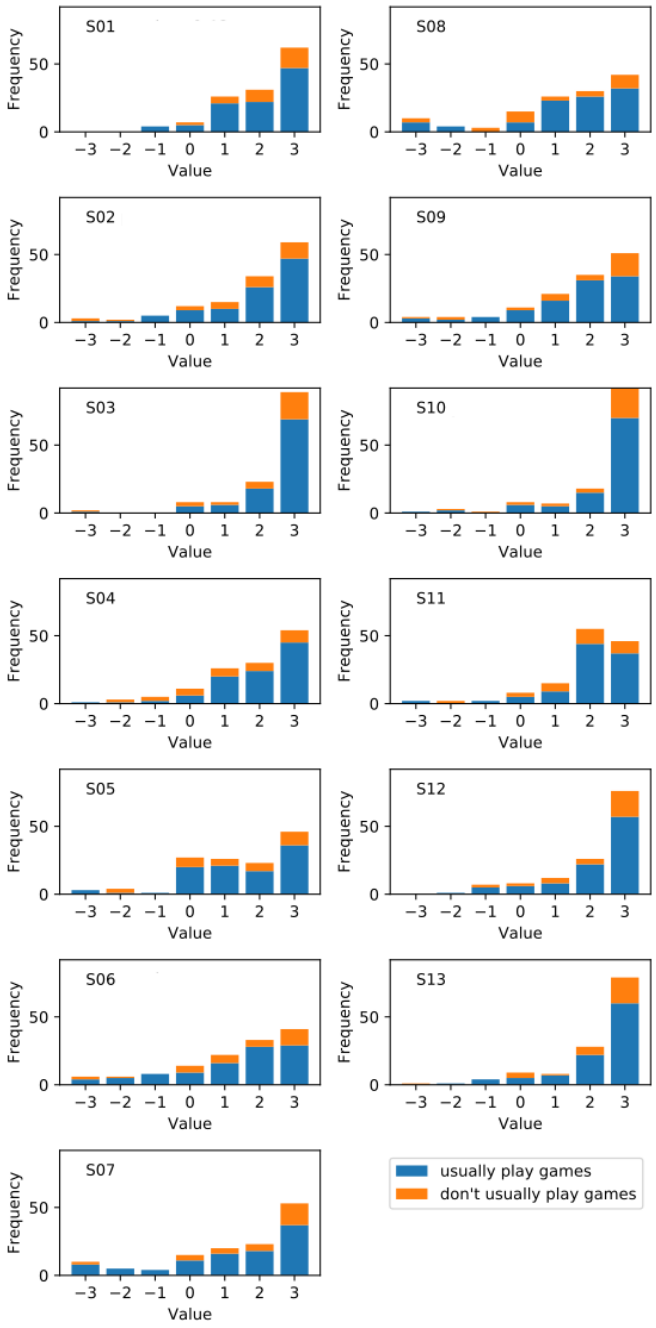

Figure 3. Frequency graphs of the value attributed to each statement evaluated in Table 1.

As it can be observed, these data do not have a normal distribution, thus, the non-parametric test corresponding to the independent T Test, the Mann-Whitney U Test was applied using the IBM SPSS Software to analyze whether the previous experience with games influenced in some aspects of the evaluation of students in relation to its usability, controls, screens, interaction with colleagues and adequacy of mechanics.

The Mann-Whitney U test showed that the fact that the student has a habit of playing / consuming games has an effect on the evaluation of the statement "S04: It was easier to understand the game" ($U = 1149.5$; $p < 0.05$), however, it has no effect on the other statements, as they presented p value> 0.05, as shown in figure 3. The habit of playing should be considered as a point of attention in research involving the use of

serious games for teaching, since it has a significant impact on what the player is able to develop in the game (Gauthier & Jenkinson, 2017). In addition to what directly interferes with student learning, it influences how the teacher will propose the use of this resource in the classroom, and its presence and guidance are indispensable for learning.

Table 2. Test statistics obtained for the Mann-Whitney U Test for statements S1 to S13 considering the independent groups of students who consume games or not.

Statements	Mann-Whitney U	p value
S1	1515	0.692
S2	1399	0.293
S3	1445	366
S4	1149.5	0.015
S5	1484.5	0.581
S6	1496	0.628
S7	1320	0.141
S8	1348	0.193
S9	1360	0.21
S10	1534	0.74
S11	1309	0.116
S12	1583.5	0.998
S13	1550.5	0.838

This result indicates how important is the presence of the teacher on explaining how to use the game correctly and the need of their presence on using this new technology on classrooms. For Meier and Garcia (2007) for the development of learning it is necessary to have an effective mediator to facilitate this interaction between the subject and the stimuli, in this context the student and the software.

The statements that received the best evaluation refer to the student being able to explore the game in its entirety, the relevance of the subject for learning, ease of manipulation and navigation in the game, which obtained, respectively, 70% and 60%.

The worst evaluations were given by 7% of the students who attributed the worst score to the interaction and challenging aspects of the game, and 6% to the perception of the passage of time. Although it was developed to be used a computer per player, the real application situation in the classroom, with a small number of computers available in the school, the software was exploited by trios of students using just one device.

The relationship with the perception of the passage of time while using the game can be related to the motivation for its use. Such data were taken in a classroom intervention situation, in which the teacher freely chose to use the game with students, which for Barendregt and Bekkerb (2010) may indicate a decrease in motivation to interact with the game, once which was the choice of the teacher and not the students.

To analyze the impact of the game on the learning of concepts related to Molecular Biology by students, the questionnaire presented in Appendix 1 was applied to 26 students.
Each question was assigned a value of 1 point, based on the average of correct answers to the questions, the following results were obtained (Figure 4).

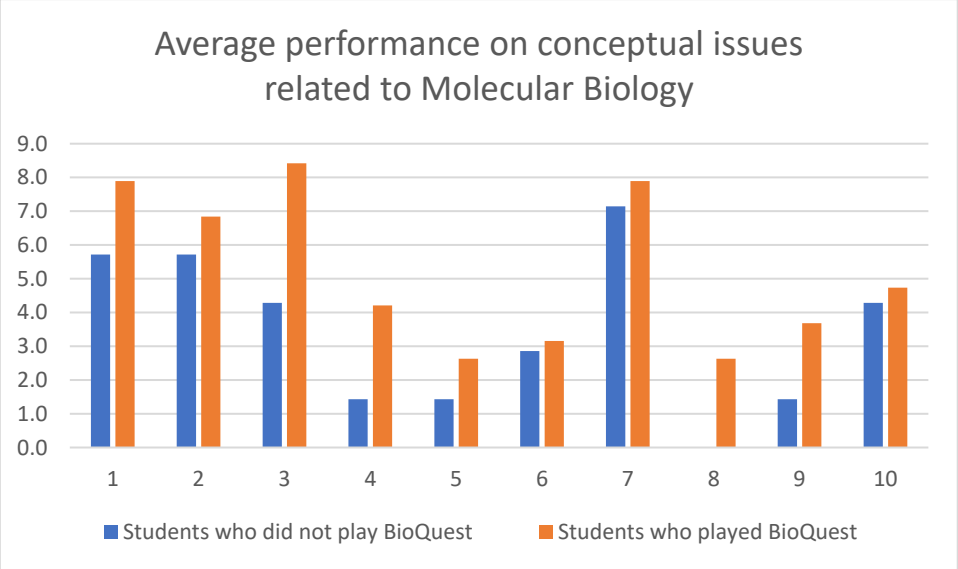

Figure 4. Average performance on conceptual issues related to Molecular Biology, both from students who used the BioQuest Software and students who did not use it.

It is noted that the performance of students who used BioQuest was higher in all questions presented.
From the answers obtained with the conceptual questionnaire, we divided the sample into two groups: group 1- composed of 19 students who had interacted with the BioQuest tool, and group 2 - composed of 7 students who did not interact, both groups had classes on topics related to Molecular Biology with the professors involved in the research. It should be noted that these students were not intentionally chosen, students who used BioQuest in the classroom and students who were absent at the time of applying BioQuest were invited to answer the conceptual questionnaire.

Table 3. Test statistics obtained for the Mann-Whitney U Test for questions 1 to 10 considering the independent groups of students who used the BioQuest Software or did not use it.

Questions	Mann-Whitney U	p value
1	52.00	0.276
2	59.00	0.599
3	31.00	0.039
4	48.00	0.195
5	58.50	0.527
6	64.50	0,885
7	61.50	0.692

8	49.00	0.139
9	51.50	0.278
10	63.50	0.841

The Mann-Whitney U statistical test showed that the use of the BioQuest software has an effect on the score obtained in question 3, ($U = 31.5$; $p < 0.05$), but did not show an effect on the scores obtained in the other questions. It is noteworthy that question 3 is related to the contents treated explicitly in phases 2 and 4.

In these two phases, gamification elements are present that promote student motivation, such as, in phase 2, use of narrative, when it is presented to the player that the DNA sample amplified by the PCR was not labeled correctly and it was swapped with others stored in the same freezer. In phase 4, the player assumes the role of the restriction enzyme to be able to cleave the plasmids which, later, amplified insulin genes will be inserted, there is a marked presence of elements of extrinsic motivation such as time markers, means not obvious, but discovered to perform tasks (manipulating the enzyme to cleave plasmids), punctuation and graphic feedback indicators (Robinson and Bellotti, 2013). Some works indicate that the presence of specific mechanics has the potential to increase the performance of a student, his willingness to participate in meaningful and intellectual games, thus improving his understanding of content and concepts (Domínguez et al, 2013; Busarello, 2016; Gauthier & Jenkinson, 2017).

5. Conclusions

In this paper we present the evaluation of the use of the BioQuest software by 131 students of the 2nd grade of High School. This is a new form of teaching developed based on interactivity.. Our results show that students are able to perceive the importance that the content covered by the game has for their learning in addition to underline that its usability and navigability is quite pleasant and easy. Regarding the impact on their learning, the data show that students performed better in questions involving concepts worked in phases of the game with more evident gamification elements such as narrative, and elements of extrinsic motivation such as time markers, means not obvious, but discovered to perform tasks (manipulate the enzyme to cleave plasmids), punctuation and graphic feedback indicators had a positive impact on learning.

6. Acknowledgement

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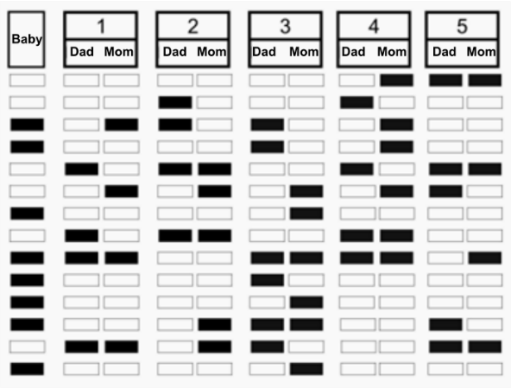
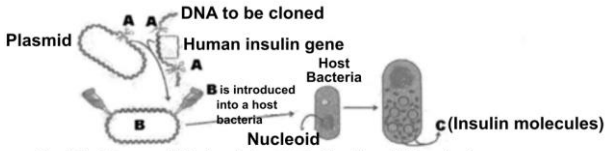
Appendix

Appendix 1.

Table 1. Questions used to assess the impact of the game on learning concepts related to Molecular Biology.

Number	Question
1	One of the techniques used in molecular biology for the manipulation of DNA is the polymerase chain reaction (PCR). The purpose of this technique is: a) Cut long strings of DNA into smaller fragments. b) Create multiple copies of a specific stretch of DNA. c) Separate fragments of different sizes due to their migration in a porous gel matrix. d) Link DNA fragments together. e) I have not studied this subject.
2	The technique known as gel electrophoresis: a) It separates DNA fragments of different sizes due to their ease in traversing a porous gel matrix, when subjected to an electric current. b) It separates fragments of DNA of different sizes because it uses enzymes that are in the porous gel matrix. c) It links DNA fragments together. d) Creates multiple fragments of DNA due to the action of the electric current on an extensive DNA strand. e) I have not studied this subject.

3	Restriction enzymes occur naturally in prokaryotic organisms, and have the role of protecting the cell against invading viruses. Its use in Molecular Biology is due to its function of: a) Link DNA fragments together. b) Create multiple copies of a specific stretch of DNA. c) Recognize and break the links between some of the nucleotides of specific DNA sequences, called restriction sites. d) Copy the nucleotide sequence from a DNA strand. e) I have not studied this subject.
4	The genetic manipulation of a plasmid, in order to synthesize a protein which the organism originally does not produce, involves: a) The cleavage of the circular DNA molecule, the insertion of the gene of interest and the link between the gene and the plasmid. b) The cleavage of the circular DNA molecule, the insertion of the gene of interest, the link between the gene and the plasmid and the bacterial transformation with the recombinant plasmid. c) The cleavage of the circular DNA molecule, the insertion of the gene of interest and the link between the gene and the plasmid and the application of specific antibiotics. d) The cleavage of the bacterial chromosomal DNA molecule, the insertion of the gene of interest, the link between the gene and the chromosomal DNA. e) I have not studied this subject.
5	During the bacterial transformation process, we give the cell a temperature shock and treat it with calcium chloride because: a) We want to create pores in the cell membrane making it easier for DNA to enter the cell. b) We want to close the pores of the membrane and cell wall preventing the DNA from leaving the cell. c) We want to open the pores of the membrane and cell wall making it easier for the DNA to leave the cell. d) This step favors the multiplication of the bacterial cell. e) I have not studied this subject.
6	One of the steps in molecular cloning is to use antibiotics on cells that have gone through the process, such as the kanamycin antibiotic, which serves to: a) Eliminate the bacteria that could contaminate the experiment. b) Eliminate the bacteria that contained the recombinant plasmid, since it contained a gene capable of disabling the action of kanamycin. c) Eliminate bacteria that did not contain the recombinant plasmid, since it contained a gene capable of disabling the action of kanamycin. d) Eliminate the bacteria that contained the recombinant plasmid, since it

	contained a gene capable of increasing the action of kanamycin. e) I have not studied this subject.
7	An exchange of babies had been detected in a certain hospital, such confusion involved five couples who claimed to be the parents of a baby. Thus, confirmation of paternity was requested by DNA examination. The test result is outlined in the figure below. Each person has a pattern of DNA bands (bands, one for the supposed dad and one for the supposed mom) compared to the baby's. Analyze the image below and answer, which of the couples can be considered as the baby's biological parents?  a) 1 b) 2 c) 3 d) 4 e) 5 f) I have not studied this subject.
8	The figure below illustrates the main steps used in the molecular cloning technique used to produce human insulin in bacterial cells: a segment of human DNA containing the code for insulin synthesis, is linked to a plasmid and is introduced into a bacterium a from which clones capable of producing the hormone in question are obtained.  Modified from: J.M. Amabis; G.R. Martho. Biologia das Populações. vol.3. São Paulo: Moderna, 2004. p. 168-69 Analyzing the figure according to your knowledge of the techniques of molecular cloning, identify with T the true statement (s) and with F, the false (s): () The letter A indicates the restriction enzyme representation. () The letter B represents a recombinant plasmid. () The letter C indicates the human insulin molecules synthesized from information given by the human gene induced to function in the bacterium. () The letter B represents the structure that, after being introduced into the host bacteria, prevents the nucleus from functioning.

	The correct sequence is: a) TTTF b) TTFT c) TFTF d) FTTF e) FFFT f) I haven't studied this subject
9	On June 21st, 2000, the sequencing of the human genome was announced, this announcement represents that scientists have determined: a) the nucleotide sequence of human chromosomes. b) all types of proteins encoded by human genes. c) the amino acid sequence of human DNA. d) the amino acid sequence of all human proteins. e) the correct number of chromosomes of the human species. f) I have not studied this subject.
10	What is Genetic Engineering? a) Set of procedures used in the manipulation of DNA. b) Process by which genes make proteins. c) Biology branch that studies human genes. d) Specialized branch in the production of scientific equipment. e) I have not studied this subject.

Answer Key: 1B, 2A, 3C, 4B, 5A, 6C, 7C, 8A, 9A and 10A.