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Project-based learning: video game development as a tool to integrate ecology, genetics, evolution and informatics

Maria A. M. Bernini, Adolfo L. Carvalho, Jaqueline Carlos-Bender*

IFSULDEMINAS campus Muzambinho, Muzambinho, Minas Gerais, Brasil.

ABSTRACT

Introduction: Active, student-centered learning encourages the development of 21st century skills and competences. Many of them encourage, in addition to autonomy, interdisciplinarity. Therefore, the participation of students in the creation and not only the stimulation of the use of technologies is extremely relevant. Considering the importance of multidisciplinarity that must involve the learning process, new approaches such as Project Based-Learning have been developed, seeking greater involvement of the students in learning-related decisions. **Objective:** Aiming the interdisciplinarity that the integrated educational system requires, the purpose of this study was to analyze the development of games as an integration tool, between biology and computing area. The games have been developed along with the subjects of Entrepreneurship and Practical Projects III. **Methods:** Classes have been held so that high school students could grasp the contents of Evolution, Genetics and Ecology, which would be the central themes of the games. **Results:** Groups who have chosen Evolution to work with had greater difficulty in understanding the content whereas those who have worked with Ecology and Genetics outdid the formers. The Game Maker program stood out being the most used tool for the game's making process. **Conclusion:** The acceptance of the project by the students leads to the conclusion that innovative methodologies such as project-based learning is a great tool in education, so that the groups could be more involved in class and the subjects could be linked together.

Keywords: Interdisciplinarity; biology; active learning; student centered learning.

*Autor correspondente (corresponding author): Jaqueline Carlos-Bender
IFSULDEMINAS
Rodovia Prefeito Quintino de Lima, 2100, Paisagem Colonial, São Roque, São Paulo, Brasil.
CEP18145-090
E-mail:jack_ufv@yahoo.com.br
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1. INTRODUCTION

The word interdisciplinary comes from the twentieth century, but the philosophy behind it is very old, as a unified science characterizing the synthesis of integration (FAZENDA, 2008).

The most important current approach to this theme is the pedagogical analysis and redefinition of an educational policy, not only the meeting or the juxtaposition of the subjects (JUPIASSU, 2006). According to Jupiassu (2006), interdisciplinary thinking promotes the union of teaching and research, where the school is the place where critically and collectively produces new knowledge.

Education is the full development process of humans and their physical, intellectual and moral capacities, aiming much more than skill building, it should also build character and social personality as individuals (ARANHA, 1996).

One of the biggest misconceptions in the teaching of biology is the lack of relationship between one subject and another, such as Genetics Evolution and Ecology. This lack of interaction between contents fragment the student's reasoning (MARQUES; SALOMÃO, 2014).

Evolution, in turn, is completely linked to Genetics, when we talk about evolutionary processes in a population, we talk about genetic mutations, gene duplication, natural selection and random recombination (NEI, 1975). According to Passmore and Stewart (2002), few students really understand the concepts of evolution, or can relate them to other topics in biology, leaving only the idea of the Darwinian model of natural selection. Regarding ecology, it is inseparable from evolution and genetics, according to Melo *et al*. (2008) there is a very shortage of teaching materials that show the importance of ecological changes with species dispersions.

In order for the student to establish these interconnections, the learning environment must facilitate this process. According to Santos and Moita (2011) the generation that is currently in the classroom does not compare with the previous ones, used to textbooks. Today's students experience the challenges through these games, showing advanced resourcefulness.

Virtual games, due to their interactivity conditions, such as places visited, can be considered spaces, adjectives as educational that, in fact, are part of the daily lives of children and young people (SANTOS; MOITA, 2011). Video games can develop or reinforce some skills, such as spatial visualization and cognitive stimulation through three-dimensional movements (GRIFFITHS, 2002).

Active, student-centered learning encourages the

development of 21st century skills and competences. Many of them encourage, in addition to autonomy, interdisciplinarity. Therefore, the participation of students in the creation and not only the stimulation of the use of technologies is extremely relevant.

Considering the importance of multidisciplinarity that must involve the learning process, new approaches such as Project Based-Learning have been developed, seeking greater involvement of the students in learning-related decisions. Thus, solving real problems enables the development of required skills to functional performance, which is quite the opposite of the traditional education systems' approach (NOBRE *et al*, 2006).

The aim of this project was to stimulate students' multidisciplinary skills promoting integration between Biology, Computer programming and Entrepreneurship subjects, by creating video games developed by the students themselves, working with Evolution, Genetics and Ecology particularly.

2. MATERIALS AND METHODOS

2.1. Students and subjects

First of all, a target audience analysis was thoroughly done, being them third-grade high school students from an integrated public school in the city of Muzambinho-MG, Brazil. After the target audience analysis is finished, a formal proposal was offered to the students, which aimed the development of games, in Portuguese, linking the following subjects: Ecology, Evolution, Genetics, Entrepreneurship and Practical Projects III. After settling how the project would be developed with the students they were supposed to pick the theme they would like to work with, and divide themselves freely.

2.2. Hands on games development

In the second semester's beginning the video games development have started through weekly meetings during the Entrepreneurship and Practical Projects III classes, which were held every Tuesday from August to December. The main idea of these classes was to help with the games' making process by helping them to better understand specific topics in Ecology, Evolution and Genetics. All the students, no matter whether they picked Ecology, Evolution or Genetics, had access to all the classes, so they could interact with all the groups and take part of everything. The meetings initially sought to assess the students' prior knowledge, so the difficulties to be worked on could be clearly categorized. After the points for development were identified, classes were held to clarify the questions, where it has been discussed from the very definition of the word evolution to more advanced concepts, such as speciation and gene flow. Regarding Biology subjects, for instance, it was possible to approach from basic concepts such as habitat settings and niche, to more complex ones, such as trophic level, global warming, human evolution and protein synthesis.

At the end of each class, the students would work on the games' development, which counted on the help of a computer science's students to provide technical support to the use of Game Maker tool. As a form of extra-classroom communication, students came up with discussion groups to ask questions making use of social networks, which enabled to answer specific questions and provide additional materials to help them.

2.3. Demo day

At the end of the game development, students could present the developed games to all classmates and teachers involved in the project.

2.4. Assessment

As a way of continuous learning assessment of the students' performance, questionnaires were applied to the groups at each topic's closing, after they have finished them, there was a correction and discussion about that, so everyone could participate.

3. RESULTS

3.1. Evolution games

- Gamer Sapiens: five students developed a hangman game using Java, where the teacher has access to the platform making a record. The teacher can launch several information that will appear on a white screen in the form of tip, see Figure 1A. The player is entitled to only know mistakes, if the student make them, he will not see the next phase of human evolution, because the current species will be hanged. This group had problems in the execution of the game.
- EV game: developed by five students, the game created in Game Maker platform shows the five commonly seen phases in human evolution, there is an explanatory screen about the game, where the *Australopithecus* is the protagonist of the initial phase. The human ancestor must overcome obstacles to evolve, for instance, to get food and not lose lives by bumping into the screen elements, see Figure 1B.

The *Australopithecus* must evolve to Homo Habilis after making it to the first level, and it will be so until the *Homo sapiens*' arrival, which is the final stage of evolution.

- The game of Dinos has interactive goal in which the player learns about the species' evolution while advancing levels. The game shows the first stage of the primitive atmospheric conditions. If the player misses what conditions are better he will not see the next step, going back to the beginning of the first stage. After hitting the ideal situation for the formation of life, the player advances to the next level. Moving forward, the player must catch food so the polyp can give rise to cnidarians. When reaching the fish kind, the player must catch the food without leaving the screen, by the end of this level, the fish will have become an amphibian. This amphibious will give rise to a reptile ancestor that now needs to harvest food scaping from larger reptiles. Due to the meteor that hits the earth, it will be extinguished, however, this catastrophe will culminate in the expansion of mammals leading to the end of the game, see Figure 2. The game is simple and made in 8 bits, alluding to Game of Thrones series, adjusting the statement You live or you die to you evolve or you die, once the game results in the extinction of the dinosaurs. The platform used for the development was Stencyl.

3.2. Ecology games

- Torquem: five students took part of this game, which was developed on the Game Maker platform and it has a different purpose, because there is no need of prior knowledge. As the player moves forward, he learns about the ecological interactions. This group presented the only game in which we have two players, showing a Brazilian ecosystem called Pantanal. Right on the first screen the player must select a continent, which will lead to the start of the game. Players have a food chain formed by the grass, capybara, jaguar

and decomposers, see Figure 3A. The capybara must eat as much grass as possible, but also run away from the jaguar, otherwise the cabybara will lose its three lives and might vanish from the ecosystem. The jaguar, in turn, needs to eat the capybara, or else it will disappear from the ecosystem as well. The game has three levels, at each succeeded one, the capybara needs to eat more grass to survive, and the jaguar needs to run faster as well. Either of them can be the winner at the end of the game, being the one who loses fewer lives, remaining in the ecosystem and perpetuating the species.

- Rick Fox x The animal world: four students developed the game using the Game Maker platform, based on the idea of the game Super Mario World, which is originally an action game. The game starts with the mission that Rick must accomplish, which is to go through the forest to save his girlfriend Rickette that is stuck on the other side, and he must face the animal world, and its food chain. Rick needs to dodge big felines that want to predate him, and he must not fall into the water, or else, he is supposed to go back to the previous stage. During the game, Rick can pick up tips that will be helpful to answer upcoming questions about Ecology, see Figure 3B. After answering all the questions, Rick can find his girlfriend, Rickette, and they can return to their former habitat.

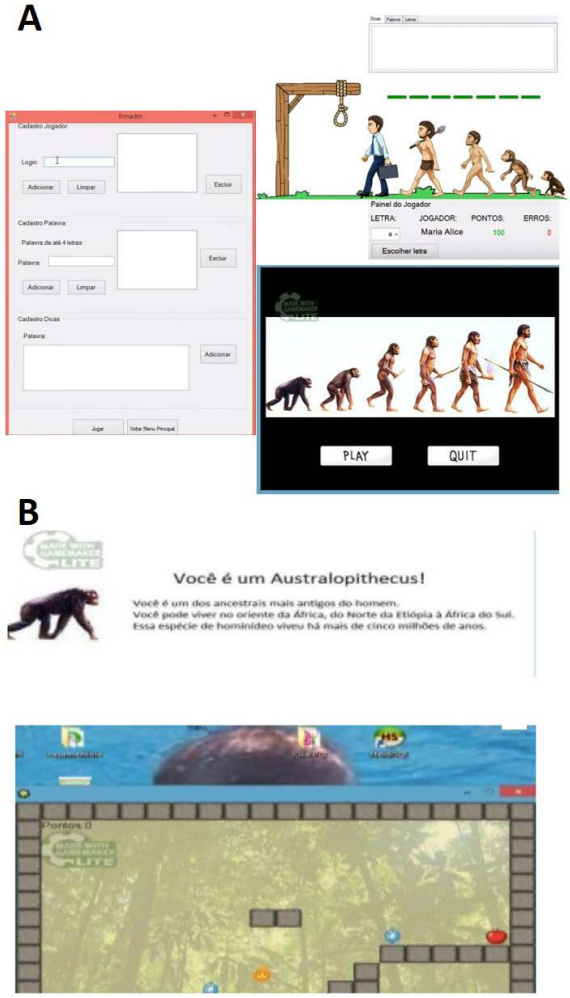

Figura 1. (A) Gamer sapiens. Screenshots of the game, which is a platform that allows the user to create challenges. The aim of the game is to get the right word through the provided tips regarding evolution**. (B) Screen EV.** Screenshots of the game in which *Australopithecus* is the protagonist. Basically, the human ancestor must overcome obstacles to evolve to Homo habilis and then to the final level: *Homo sapiens*.

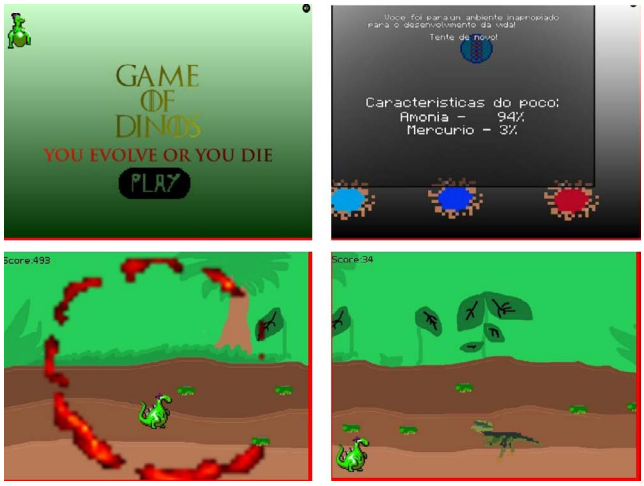

Figura 2. Game of dinos. Screenshots of the game in which the player goes through several stages of human evolution starting from the living-being's existence. After completing each level, the player moves to water evolution, going afterwards to the terrestrial ecosystem.

3.3. Genetics games

- Mario Bio: this game is about basic concepts such as amino acids and genetic inheritance to more complex ones like protein formation, once the game would display the insulin synthesis. The game has the home page in which the player can get information or go straight to the first level. The ribosome scientist will give Mario, who will be the RNA carrier, the mission of finding the right amino acids to help the princess make insulin for her own survival. He is supposed to travel through the pancreas beta cell trying to find the necessary amino acids so he can build the insulin chain for her. Each enemy he eliminates adds up to the necessary amino acids at the top of the screen. As soon as he can complete the representative sequences in the game, in this case leucine, tyrosine, serine, guanine, valine and glycine he will pass to the next level (Figure 4A).

- ChromosomeSix: this game featured an introduction in which the player would have information about four syndromes, namely: Down Syndrome, Cri Du Chat Syndrome, Klinefelter Syndrome and Edward Syndrome. The students used Game Maker tool. To pass the levels the player would have to put together the 23 pairs of human chromosomes in order not to finish the level with a syndrome. As an obstacle to this game the screen is maze-shaped. The player must dodge his opponents and race against time, if bumping into an opponent, or not picking chromosomes within time, questions will appear on the screen about syndromes. If the player hits the question, he moves on to the next phase. After four stages like this one answering the questions correctly, the player will reach the end of the game by accomplishing his goal, which is to win without any syndrome (Figure 4B).

-Mendel's Secret Garden: Mendel is the protagonist of the game, who must go through the monastery picking peas in the first level, where he is supposed to answer questions about his 1st Law. After passing the level, Mendel should pick carrots and answer questions from the rabbit about polyalelia. Afterwards he must reach the last phase that takes place at a hospital, where questions about the ABO system should be answered. At each player error points are lost that can return him to the previous level (Figure 4C).

Figura 3. (A) Torquem. Screenshots of the game, which has a few characters from the food chain and the player must ensure their feeding. At the end of the game, the winner is who lost fewer lives and fed properly. Then, it begins a cycle of decomposers. **(B) Rick fox x the animal world.** Screenshots of the game, in which the player's mission is to find his lost female in the forest escape from his predators. If the player falls into the water or is caught by the predator, he must answer ecology questions to continue.

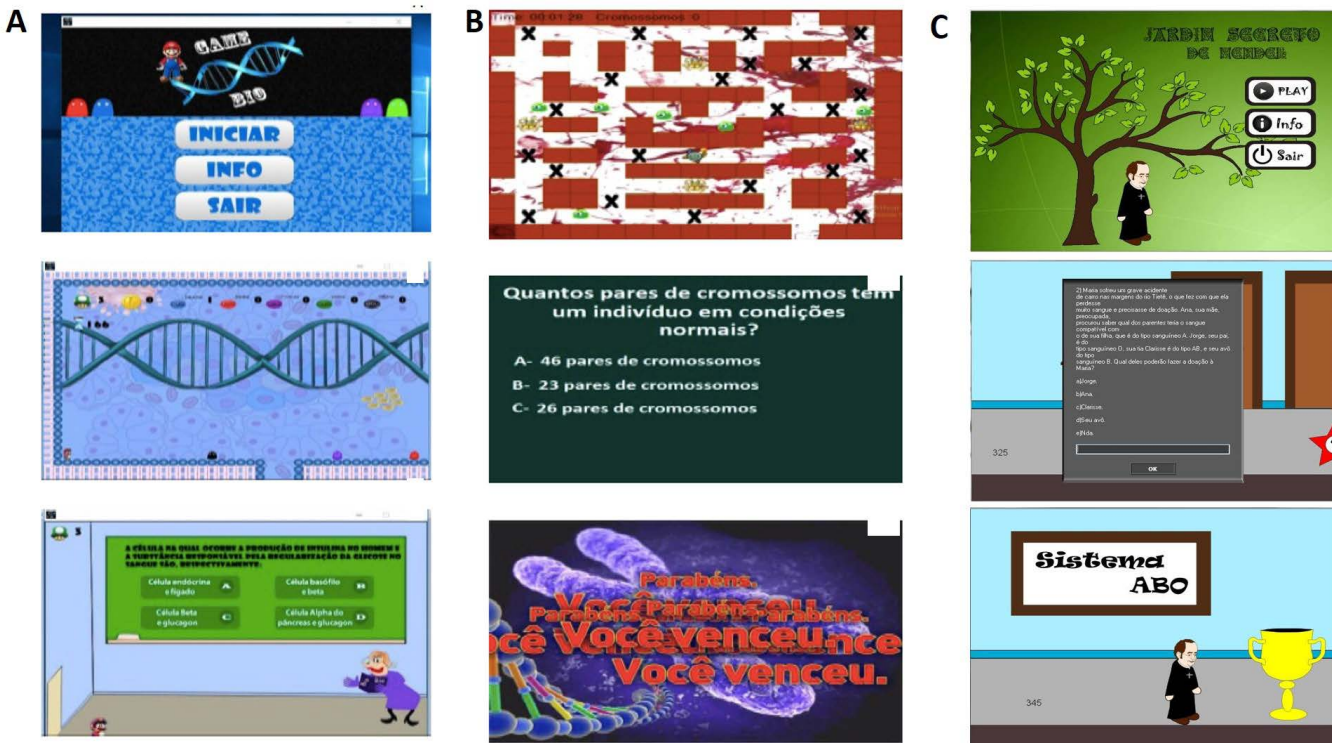

Figura 3. (A)Mario bio. Screenshots of the game, in which the player Mario must find the right tRNAs and answer questions about protein synthesis to move on to the next level. One part of the game takes place inside the pancreatic beta cells showing the insulin synthesis. **(B) ChromosomesSix.** Screenshots of the game, which displays some information about chromosomal syndromes and the player must answer questions to advance the levels and finish the game. **(C) Mendel's Secret Garden.** Screenshots of the game, which takes place in a monastery and the player goes through 3 stages, picking herbs and answering genetics questions.

4. DISCUSSION

The students divided according to their groups, made great use of social networks and apps as a tool in order to asking questions, once they became frequent during the game production particularly at extra-class moments. The questions would be clarified every day according to their needs. Collaborative tools assist in the learning process by stimulating communication and collaboration. Such networks ease the communication and sending links, videos and articles. For the Evolution theme three groups were formed, which explains the general interest of the students, since this is considered the topic that puts into perspective the understanding of natural phenomena and the history of science, also inciting the curiosity of students (TIDON and LEWONTIN, 2004).

According to Queiroz (2012) games like Gamer Sapiens is regarded as an educational game, and it can be a very useful and interactive tool in the classroom in any matter. However, the Java tool presents a greater difficulty level to be worked with, with difficult repair codes, clearly being the biggest problem faced by this group in the execution of the game.

The EV group presented minor results working with human evolution concepts. The group had difficulties during class to associate the content with what they would approach in the game. According to Passmore and Stewart (2002), very few students really understand the concepts of evolution, or are able to link them to other topics in Biology,

being narrowed only to the idea of Darwin's natural selection model.

The purpose of this group presents technical errors in the order of human evolution and a background with setting the same for all stages. When asked during the presentation about the basics of evolution matters we learned in class, the group faced difficulties in answering them. Which, might be common, according to Moura and Santana (2012) students carry questions during their training, often for lack of adequate teaching materials or unpreparedness of teachers, which leads to lack of interest of students.

The students that developed The Game of Dinos had the best prior knowledge about Evolution. These students were curious in class asking many questions, which is common because when it comes to Evolution, it reveals itself as a subject surrounded by epistemological obstacles and theological foundations that might create barriers inside the classrooms (OLEQUES *et al*., 2012).

The greatest difficulty to work with this group was the concept of common ancestors and its branches, so they could understand that evolution is not a linear and quick process that gives rise to another species easily. This kind of thinking seems to be ingrained in high school students' minds, and the teachers are held responsible most of the times, by not addressing this issue correctly (TIDON and LEWONTIN, 2004).

For the Ecology theme were formed two groups, showing a certain lack of interest at first, which according to Melo *et al*. (2008) may occur because there is a major lack of teaching materials that show the importance of ecological changes regarding the dispersions of the species and Evolution.

The Torquem group presented a simple game, however, they showed great skill at talking about ecosystems, with aspects such as balance of the chain, biotic and abiotic factors. Showing that according to Mizutani (2010), Ecology shows the interaction between living individuals and non-living materials, and, to address this issue it's required that the students understand how the planet works regarding to changes and its implications.

The Rick Fox x The animal world game features some flaws in the content and explanation of the ecological interactions portrayed on it, unlike the Torquem game students did. In this group, students forget to link abiotic factors to the forest, not showing precisely how wider relations could have been. It shows, according to Mizutani (2010), that not every student is able to do well when the subject is broad like Ecology is.

For the Genetics theme 3 groups were formed showing great interest on the content particularly when it comes to genetic syndromes and inheritance.

The Mario Bio students faced difficulties in abstracting the concepts learned, and putting in to the game. Realizing this difficulty, Topcu and ŞahİN-pekmez (2009) could conclude that high school students were used to memorizing genetics contents and when it comes to going calculations, such as Molecular Genetics, they had difficulties to relate content to real situations. This group was the one that had more questions about Genetics, especially in the process of transcription and protein synthesis. What is not uncommon, because, according to Carboni and Soares (2007), what is observed today in high schools is that the contents related to Molecular Genetics have been superficially approached, or there is an absence of representative models.

During the development of the game ChromosomeSix, the group of six students had fewer questions about the content of Classical Genetics in the classes taught. Showing themselves not so interested in the game making. This game presented a simple and informative proposal, but it presents some conceptual errors regarding the representation of the shape of the chromosomes in the duplication situation. The game shows what is very common among students which is the representation of chromosomes in the form of an X, because this image is often used by teachers in class and found in many textbooks (SILVÉRIO; MAEStRELLI, 2011). There is a great difficulty on the part of the students to learn about this theme, especially when it comes to the mechanisms that involve chromosomal alterations, cell division, DNA and anomalies, since they are presented in a fragmented way (PARANÁ, 2009).

The need for more research on the teaching approaches of genetics and molecular biology in Brazilian schools is becoming increasingly evident (MELO and CARMO, 2009).

Mendel's Secret Garden game development process, this group of 5 students did not have difficulties regarding the content they would put in to the game. For being high school students related to computing area may explain the ease of working with Mendelian Genetics, once Haambokoma (2007) found that 22% of students do not understand this subject due to the lack of a satisfactory background in mathematics.

Students in other groups in the room tried to answer the questions more enthusiastically than in the other Genetics games, creating discussions about the results of the proposed cross-questions. In his work with students in Washington doing phenotype and genotype testing through a simple game (OMOTO, 1998) realized that the discussion lead by the different groups was essential for knowledge building and should not be rushed.

5.CONCLUSION

Project-based learning is an effective integration tool when it comes to bringing different areas together, in this paper, Biology, Computer Science and Entrepreneurship. At the end of this work, the students realized that Evolution, Ecology and Genetics walk alongside, how important to work with the right platform was to better sell their games in the market, and how important the teamwork was to the final result. More project-based learning works should be developed in integrated educational system schools to reach student's interest for the subjects, enabling them to see themselves in their future carriers.

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CONFLICT OF INTERESt

The authors declares that there is no conflict of interest regarding the publication of this paper.

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