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A Serious Game for Public Engagement in Synthetic Biology

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Abstract. Science gamification is an alternative way of science communication aimed to enhance public engagement in the dialog between scientists and broad audiences. This approach conveys information through an informal environment where individuals are more likely to engage in new knowledge areas. One of such new areas is synthetic biology, which aims to apply engineering principles to biology and create new biological parts or systems, or re-design existing biological systems for useful purposes. Biofaction developed the educational game SYNMOD, aimed to communicate basic scientific principles of synthetic biology, in an entertaining and engaging way. The game is based on the SYNMOD project, which aimes to design and produce novel antibiotic molecules. The aim of the game is to help memorize the names and 1-letter codes of 20 standard amino acids, provide additional information about amino acids, explain the modularity of lantibiotic synthesis, and stimulate further interest to synthetic biology among players.

Keywords. Science gamification, synthetic biology, SYNMOD, lantibiotics, amino acids.

1 From Science to Science Gamification

Nowadays science is progressively getting more complicated and specific, which consistently moves it away from lay people. While the most accurate way to present the results of a scientific study is to present the study itself, it requires a considerable scientific background in both the audience and presenters, which is very often not the case. In order to overcome this problem, popularization of science needs to be applied, presenting a scientific topic in a manner that can be easily understood without pre-existing knowledge. Science communication and public engagement employ numerous approaches, including science gamification. Games can be seen as an alternative way of science communication that acts through an informal environment where individuals would be more open to engage in new knowledge areas (Torrente, Moreno-Ger, Martínez-Ortiz, & Fernandez-Manjon, 2009). Information is represented in familiar forms that individuals can relate to and enjoy, while the message is integrated naturally in a context, and communicated in a language that the target audience better understands (Whitton, 2007; Wideman, Owston, Brown, Kushniruk, Ho, & Pitts, 2007; Sharples, 2006; Sandu, & Christensen, 2011).

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The notion of gamification refers to the use of game design, mechanics and techniques to promote and enhance non-game activities, such as education, sales, or health. Its goal is to encourage people to perform tasks considered to be boring (learning, memorizing data, developing automatic technical skills, performing routine tasks etc.) by means of making these tasks more engaging, enjoyable, and motivating (Deterding, Khaled, Nacke, & Dixon, 2011).

Communication of science through a game helps players to develop a new set of mental and physical capabilities due to such characteristics of a game environment as freedom to fail, to experiment, to exert an effort, and, finally, to interpret the results of one's own activities (Gunter, Kenny, & Vick, 2008; Klopfer, Osterweil, & Salen, 2009). Further activities support a learning process: defining a goal and moving towards its accomplishment, collaborating or competing with other players, and overcoming obstacles.

Science and game design are mutually dependent on each other. A scientific approach can make games more appealing to the audience by providing a meaningful goal and a nearly real life experience. Also, games enable experimenting with the game environment to figure out the best way to achieve the goal. In a good game that players enjoy, the experiments should be rewarded in a way that stimulates further experimenting. The player should also understand what experiment is being conducted at any given time, how well it succeeds or fails, and what variables it depends on. Using this approach can bring a lot of detail to a computer game world.

According to Henson and Blake, games can educate, engage, and create space for experimentation and research (Henson, & Blake, 2011). As such, gaming has very large potential for science engagement, and the games industry needs to establish collaborations with scientists in order to creatively and technically design and represent scientific information (Facer, Joiner, Stanton, Reid, Hull, & Kirk, 2004; Murphy, 2011).

However, it is very important to maintain the balance between playability and the addition of any extra information in order to create a truly “scientific” game. Another important issue for a meaningful communication is the relevance of game design to the information being communicated. The majority of simple scientific games run into two extremes: either they represent modifications of entertaining games, which provides only superficial knowledge about the topic, or they represent interactive real scientific problems that provide almost no entertainment (Wideman et al., 2007). Very often settings of such games do not correspond to their storyline, or the activities a player is required to undertake do not have anything in common with the outcome of the game.

2 A Synthetic Biology Mobile Game

Synthetic biology (SB) is a new and emerging field of science and engineering. Its aim is to apply engineering principles to biology. Although SB was already mentioned 100 years ago by the French scientist Stéphane Leduc, the term was “re-invented” about a decade ago by MIT engineers who wanted to make biology easier to engineer (Campos, 2009; Campos, 2012). The most commonly used definition

describes SB as the design and construction of new biological parts, devices, and systems, and the re-design of existing, natural biological systems for useful purposes. SB as an interdisciplinary field brings together experts – and their scientific cultures - from a number of different areas, most notably biology, biotechnology, genetic engineering, chemistry, nanotechnology, engineering, and informatics (IT). Applying the toolbox of engineering disciplines to biology, SB engineers attempt to realize a whole set of potential applications such as novel chemicals, pharmaceuticals, and biofuels (Schmidt, 2012).

Previous communication studies have shown that the core principles of SB are frequently omitted in traditional communication processes, such as newspapers (Kronberger et al., 2012).

The SYNMOD game is an effort of Biofaction to design an educational game that communicates some of the key scientific principles of SB but that is also entertaining, engaging, and motivating at the same time (Annex). The game was developed for mobile devices because of their constantly growing popularity and the usage not only for communication purposes. Along with entertainment applications, there is also an opportunity to promote educational experiences via mobile devices. Given that the success and popularity of a mobile application is directly related to the number of devices it can run on, we have chosen the most popular operating systems – iOS and Android.

Our approach is further supported by numerous studies devoted to the concept of mobile game-based learning (Roschelle, 2003; Collins, 2005; Sánchez, Salinas, & Sáenz, 2007; Suki, & Suki, 2007; Sharples, Arnedillo-Sánchez, Milrad, & Vavoula, 2009). According to Robertson (2011), small simple games for mobile devices are the most likely arena for future science communication. Advantages of mobile interface for the Synmod game include:

- Mobility allows users to access the contents exactly at the moment they need it without restrictions related to place or time.
- Mobile devices are perceived by the majority of people as “cool gadgets”, which can motivate in particular young people to use mobile-based learning applications.
- Technology-enhanced learning stimulates motivation of players, promotes creativity, provides short and effective feedback cycles, and facilitates the development of analytic and problem-solving skills.
- Small mobile games are not too expensive to produce, can be made freely available to users and have broad reach.
- They allow a combination of gaming and scientific content.

2.1 Game Context

The project SYNMOD, funded by the European Science Foundation,[1] applies a comprehensive SB approach to the design and production of novel antibiotic molecules. More and more pathogenic microorganisms have become multi-drug resistant and few antibiotics remain available to combat these bugs. SYNMOD aims

[1] See: http://www.esf.org/coordinating-research/eurocores/running-programmes/eurosynbio/projects-crps/synmod.html

to produce novel antibiotics through modular shuffling of existing peptide modules, thus providing an antibiotic design and production system of unusual robustness and predictability. The scientific project consisted of several steps:

- Peptide modules, obtained from peptide antibiotics (lantibiotics), were defined and re-combined in order to detect novel antibiotic activities stemming from these new combinations.
- Post-translational machinery of reduced complexity was assembled using thoroughly characterized expression elements. It was created in a way that makes it context-insensitive, i.e. suitable to be incorporated in any microorganism.
- The machinery was implemented in the bacteria *Staphylococcus carnosus*, which served as a chassis to produce preparative quantities of a variety of novel lantibiotics.
- Based on this project, Biofaction developed a computer game aimed to demonstrate how the active antibiotic assembly line works.

2.2 Game Objectives

The game serves as an educational tool for a target audience of high school students and others interested in synthetic biology, medicine and biology in general. Specifically, the game is designed to:

- help players memorize the names and 1-letter codes of 20 standard amino-acids;
- provide additional information on the structure, functions, interactions, and the biological role of the amino acids (accessible via the PubChem web site);
- explain the modularity of lantibiotics synthesis;
- provide a “first-hand” experience in the synthesis of biologically active molecules with real-life outcomes;
- stimulate interest to synthetic biology and motivate players to learn more about it.

2.3 Game Design

The game was designed by Camillo Meinhart and Markus Schmidt from Biofaction. The colaboration of a filmmaker (Camillo Meinhart) with a scientist (Markus Schmidt) enabled a gamedesign that combines entertaining qualities with scientific accuracy. The grafic design followed a previously produced animation film "The Synmod Team" (https://vimeo.com/27490490) and was also created by Camillo Meinhart.

Sound design was done by Moritz Walmueller in collaboration with Camillo Meinhart.

Genre:	Puzzle
Game elements:	Drag-and-drop
Game content:	Science and humor
Theme:	Synthetic biology
Style:	Cartoon
Game sequence:	Simulation
Game taxonomy:	Non-fiction Simulation/Game

Player immersion:	Strategic
Technical form:	2D graphic
Control:	Haptic
Number of players:	1 player at a time
Distribution:	Available for free download at AppStore and Google Play

Key Features. The game has two major environments: the peptide slot machine environment and the amino acid environment.

Peptide Slot Machine Environment

The game features 5 levels that correspond to 5 pathogenic bacteria a player has to eliminate. Bacteria are represented as cartoon "nasty bugs" that change their facial expression and sound depending on the level of efficiency of an antibiotic. The degree of efficiency of the novel antibiotics that has to be assembled in the slot machine can be 0%, 20%, 40%, 60%, 80%, and 100%, which correspond to the neutral expression in the beginning of the game, laughing at 0% efficiency, being serious at 20%, unsatisfied at 40%, angry at 60%, about-to-die at 80%, and dead at 100%.

Each new combination of peptide modules may bring additional percentage to the efficiency, but may also decrease it. A player is free to choose the mode of play – s/he can assemble all modules at first and then combine them one-by-one, or assemble them one-by-one whilst testing for efficiency.

A slot machine presented at start contains 5 wheels, 3 of them have 5 slots for peptide modules, and 2 of them – 4 slots for peptide modules and 1 empty slot each (to indicate that several antibiotics can be build up of 4 modules instead of 5). The total number of peptide modules that are used is 23, and they are the same throughout the game.

Players' controls include a "Test" button to test a newly assembled antibiotic, a "Reset" button to reset the progress in the game (both are available from the main screen), and a "Return" button to return to the main screen, available at the module-assembling screen (Fig. 1).

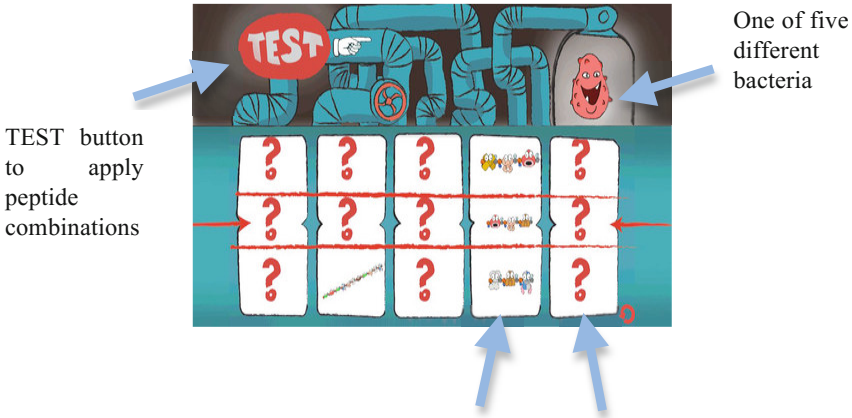

Fig. 1. Screenshot of the slot machine environment

Amino Acid Environment

The peptide modules for the slot machine have to be assembled in the amino acid environment. Amino acids are depicted as cartoon creatures, whose shapes remind on their function or source of origin (e.g. Lysine, which is contained in such foods as meat, eggs, milk, is depicted as a bone; Serine, which takes part in transmission of brain signals, - as a brain etc.) The game features 20 standard amino acids, 3 uncommon ones, and sulfur bonds between 2 molecules of Cysteine (called Lanthionine). Connection of two amino acids results in release of a water molecule (Fig. 2).

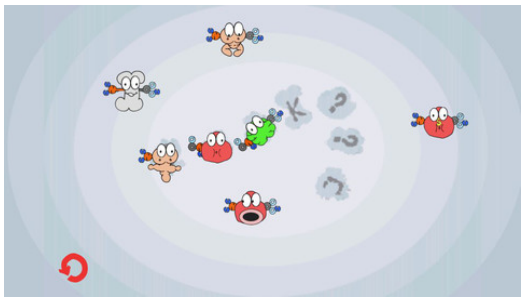

Fig. 2. Screenshot of the amino acid environment: peptide chain assembling

Game Play. The final goal of the game is to destroy all 5 bacteria by means of synthesizing a novel antibiotic remedy that has 100% efficiency against the given bacteria.

The start screen depicts the slot machine, a bacterium, and a pipeline that transports a synthesized antibiotic to it. Operating buttons, visible for user at this stage, include a "Test" button (upper left corner of the screen), and a "Reset" button (lower right corner of the screen). An arrow on the left side of the slot machine indicates the row, which contains peptide modules forming an antibiotic. From the beginning of the game, 5 synthesized peptide blocks are provided (1 on the second wheel and 4 on the fifth wheel). Other slots are marked with a question mark to indicate a peptide module to be assembled, or an "X" mark to indicate an empty slot.

In order to create a missing peptide module, a player is required to press any question mark, which forwards him/her to the amino acid environment where a set of amino acids is provided. The scheme of the module (represented by the shapes of amino acids) is situated in the center of the screen, with one amino acid being permanently anchored in the first position, and the rest distributed randomly over the screen. The amount of the amino acids provided corresponds to the number of empty positions in a peptide module. The only one button available for the player is "Return", situated in the lower left corner of the screen. The player is required to drag each amino acid on the place specifically assigned for it using a fingertip. Every time the player touches an amino acid, its name can be heard.

Two hints on how to place the amino acids correctly are available for the player: some of the shapes contain a 1-letter code commonly used in biology (that do not, however, correspond to the first letter of their full names); shapes of the amino acids correspond to their shapes provided in the empty positions.

Some of the peptide modules are linear, but some of them contain loops, made by sulfur bonds between 2 amino acids. Loops are being formed immediately during the game.

Upon the completion of the level (by having eliminated one type of bacteria) the slot machine re-shuffles the peptide modules and new bacterium appears immediately. In the end of the game the player receives a message: "Victory! You have successfully found a solution against all bacteria!". S/he needs to press the "OK" button, which forwards him/her to the screen with the completed slot machine and the first bacterium. In order to start the game again, the player needs to press the "Reset" button.

Time of game play required to complete one level is approximately 15-20 min; the time to complete the whole game is approximately 60 min. Upon the completion of the game, a player can reset the progress and start playing again.

3 Conclusion

The first version of the game is available for download at AppStore and Google Play (http://www.biofaction.com/project/synmod-mobile-game/). Further work will include the usability and playability testing of the current version of the game. The data obtained from this evaluation will be used to introduce a number of improvements in the second release of the game. Further evaluation will be conducted to determine the effectiveness of knowledge acquisition while playing the game.

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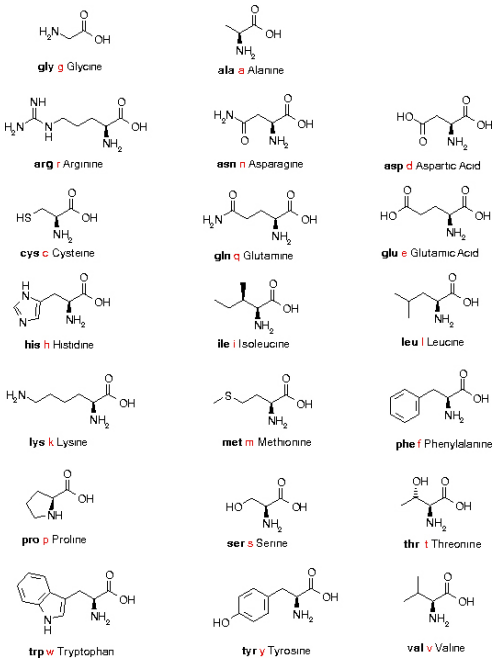
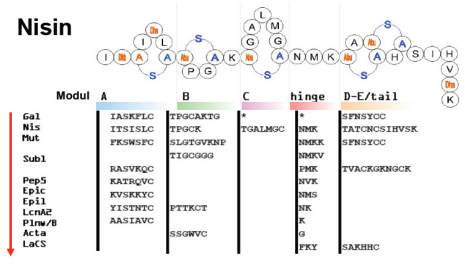
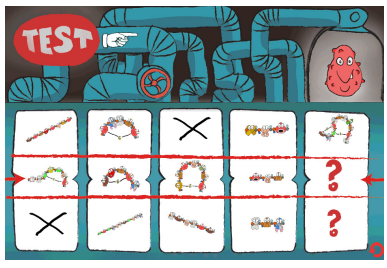
Appendix: Our Way to Translate Science to Lay People

Real Science	**Our game**
	
	

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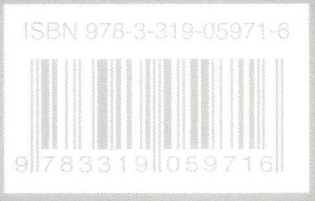

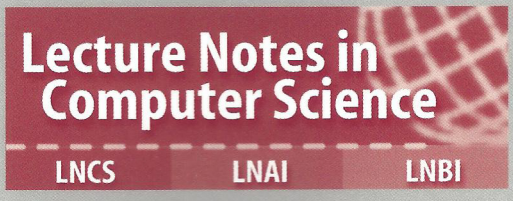

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