Promoting Learning and Engagement in Human Computing Games: a Study of Educational Material Formats

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Abstract

Many human computing games opt for transforming the problem into a more abstracted version, in order to attract as many casual players as possible. We are interested in finding the best way to include educational material in those games as a way to promote scientific learning and engagement. In this study, we evaluated three different formats of educational material in the context of a human computing game in genomics: texts (with figures), cartoons and videos.

1 Introduction

In recent years, human computing and crowdsourcing have become increasingly popular to tackle problems that are non-trivial for traditional computing approaches, or to complement machine learning approaches when training data is scarce (Holzinger 2016). The problems are usually decomposed into smaller tasks that are often distributed to human workers on platforms like Amazon Mechanical Turk (Inc 2018), and completed in exchange of a monetary compensation. Another approach is to embed the task in human-computing game (also called Game With A Purpose, or GWAP), and rely on the engaging aspect of the game for motivating the workers/players. Many GWAPs have been developed recently to target problems from many different disciplines, such as deep learning (Sullivan et al. 2018), astronomy (CCP 2017; Bouchy, Marmier, and Turner 2018), neuroscience (Kim et al. 2014), health sciences (Alvare and Gordon 2015) and molecular biology (Cooper et al. 2010; Kawrykow et al. 2012; Lee et al. 2014).

Most GWAPs based on scientific problems are also called *citizen science* games. The first step in the development of a citizen science game is to "gamify" the problem: in other words, try to add game mechanics (points, levels, rules, challenges, etc.) to promote the interest and engagement of the players. Many times, the problem also needs to be "translated" into puzzles that are more accessible to players who don't have the necessary scientific background for completing the original tasks. Citizen science games vary a lot in their so-called *level of abstraction* (i.e. how transformed/simplified the in-game puzzles are from the initial problem). In some games like FoldIt (Cooper et al. 2010), which asks its players to fold proteins in 3D following the complex rules of biochemistry, there is not a huge abstraction from the scientific problem. In other games like Phylo (Kawrykow et al. 2012), where players are asked to match colored blocks, the puzzles are very abstracted from the original bioinformatics problem of creating a multiple sequence alignment of nucleotide sequences. Both strategies for citizen science games have advantages: games with puzzles that are similar to the original problem can better motivate and engage players who are interested in science (Curtis 2015), whereas more abstract games have the advantage of simply being more accessible to a larger audience.

We are interested in developing ways to add educational content in citizen science games that have a high level of abstraction from the original problem. In other words, the goal is to develop games that are abstracted enough to be widely accessible, but that also makes it possible for players to learn more about the problems they are solving and the science behind it. In this work, we focus on the first step toward this ultimate goal, which is trying to understand the best way to present educational material in the context of a citizen science game.

For this study, we developed three different formats of educational material to test with a citizen science game already developed in our lab: (1) text format (with figures), (2) cartoon format and (3) video format. Using quantitative and qualitative analyses, our goal is to identify the format which will offer the best compromise in terms of learning outcomes (knowledge gain and retention) and engagement.

2 Methodology

2.1 Description of the human computing game

The human computing game used in this study, first presented in (Singh et al. 2017), was developed to solve a problem in bioinformatics called the *genome sorting problem*. Let S_1 and S_2 be two strings of characters on an alphabet A. Each character $c \in A$ represent a gene, and each string represents an ordered sequence of genes (also called gene orders). The solution to the genome sorting problem is the shortest sequence of events that can transform S_1 into S_2, using a predefined set of possible operations, which represent biological events that can occur during the evolution of genomes.

In the game, we use colored shapes to represent the different genes. In each level, two rows of colored shapes represent the two gene orders being compared. The top row is the *target* row, while the bottom row is the *mutable* row, *i.e.* the one that has to be modified by the player to transform it into the target. Players can modify the mutable row by selecting one or multiple genes (colored shapes), and applying one of the three possible operations: duplication, deletion or inversion. In the case of a duplication, the player must also choose where the duplicated copies should go in the mutable sequence. A deletion will make the selected genes disappear from the mutable sequence. Finally, an inversion event can only be applied to selections of genes that contain the *terminus of replication* (represented by a black dot near the middle of the row). This is simply because inversions are known to occur mostly around this *terminus* in the gene orders considered in this game. A screenshot of the game is presented in the supplementary material (see Figure 2).

2.2 Production of the educational material

Since the human computing game is aiming to solve a problem in bioinformatics, the educational material is also about topics in bioinformatics. We chose 3 different topics that are related with the game, and since there is a logical progression between the topics, we always present them to the participants in the same order.

For each topic, three versions of the educational material were prepared by the authors: one in text format, one in cartoon format and one in video format. The scientific content represented in the educational material was produced by an expert in bioinformatics to assure its quality and accuracy. The same scientific content was used in the three formats for each topic.

The text format is the simplest one: for all three topics, in consists of approximately one page of text with some figures that were added to help demonstrate some of the concepts (see Figure 3). The cartoons were created using *ComiPo!* (Corp. 2014), a software for creating manga-style short stories. In the cartoons, characters are presenting the scientific material through their interactions (see Figure 4). The videos were created using the *VideoScribe* (Sparkol 2018) software tool, which creates hand-drawn animated videos, using a sequence of figures provided by the user. During the video, a narrator reads the same text that was presented in the text format (and cartoon, but without the characters and story which is unique to the cartoon format). The videos for all topics are on average 2:45 minutes long (see Figure 5 for a screenshot).

2.3 Experimental design

In this study, there is one independent variable: the format of educational material (text, cartoon or video). The dependent variables are knowledge gain (quantitative), and user interest and engagement (qualitative). In order to measure knowledge gain, we used a pre-test, presented at the start of the experiment, which contained different questions than the post-test which is taken after the presentation of each topic.

The main part of the experiment consisted of three rounds (one round for each topic). In each round, the participants were invited to:

1. learn about a specific topic using one of the three formats (more details on the assignment of formats below);
2. play the game for 5 minutes;
3. answer a short quiz (5 questions) about the topic;
4. answer four Likert scale questions about the format that was just presented to them.

The 5 minutes of gameplay were purposefully placed in between the presentation of each topic and the quiz so that we can evaluate if the participants are able to retain the information they learned after completing a different task.

As mentioned previously, the order in which the topics are presented is the same for all participants. However, the three different formats are presented to the participants in all 6 possible orders. The 6 possible orders of formats were each completed by 3 different participants.

After completing the three rounds, the experiment was concluded by conducting a semi-structured interview with the participants.

3 Preliminary Results

We recruited 18 participants (5 female) in a university. The average experiment duration time was 45 minutes and each participant received a $10 gift card as compensation for their time commitment. 55.6% of the participants were undergraduate students and the rest were graduate students.

As shown in Figure 1, the majority of participants have chosen the video format as their favourite way to learn the material. We also analyzed the proportional difference between the scores obtained in the pre-test and the post-test as a way to measure knowledge gain in this experiment (% increase in correct answers). Surprisingly, the three formats yielded similar knowledge gains, with the text format coming in first.

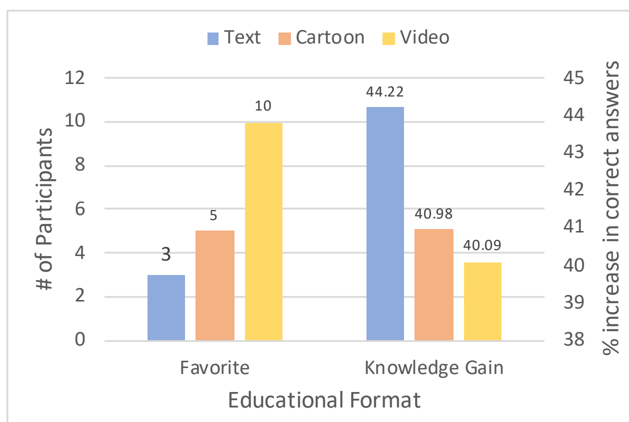

Figure 1: The left Y-axis shows how many participants prefer each educational format. The right Y-axis shows the % increase in correct answers after being shown the educational material.

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4 Supplementary Material

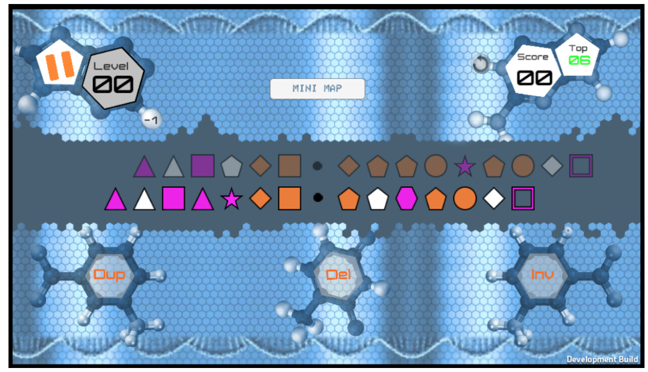

Figure 2: Screenshot of the human computing game

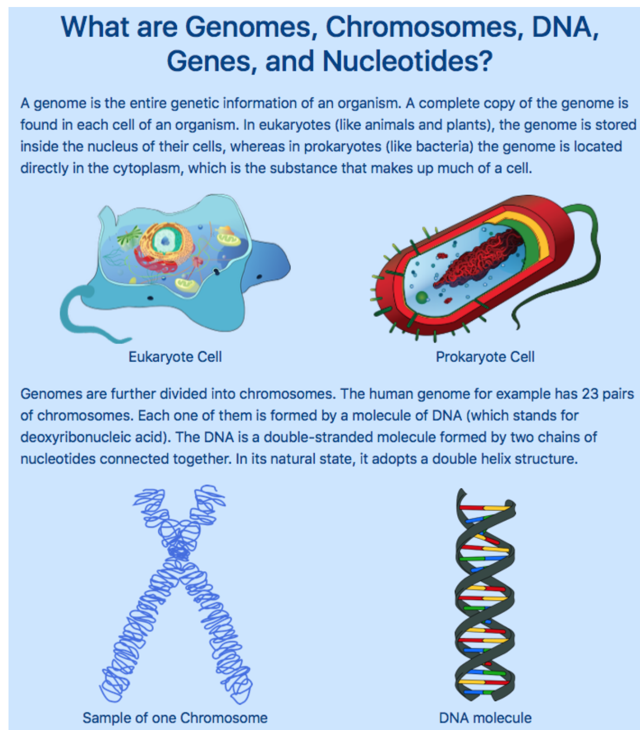

Figure 3: Example of the text format

Figure 4: Example of the cartoon format

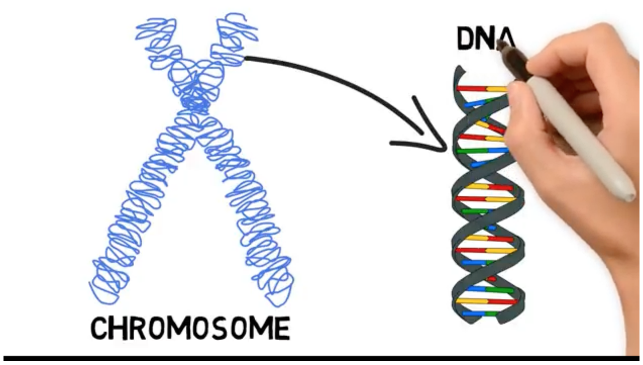

Figure 5: Screenshot of the video format