CocoGame: a funny app to learn physics and math

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***Abstract*— A web game-based platform was designed for mobile devices in order to improve the conceptual comprehension of Physics and Math. A *gamification* approach is used to engage the students and to encourage youngsters to venture into science, technology, engineering and mathematics. Recognition is earned through stars and other awards that can be redeemed as the students play *CocoGame*. In this way *Cocol*, the central character of the game, grows in wisdom and strength. An interdisciplinary team of professors of Physics, Math and Computer Sciences at the Tecnológico de Monterrey, Campus Ciudad de México developed the academic content and designed the Web platform. Currently, tests of the web platform are being conducted. A pre-test/ post-test approach is being implemented with undergrad students in control and experimental groups, as an attempt to measure the impact of the usage of our platform in the students' academic performance.**

Keywords—Gamification, Apps, Physics, Mathematics

I. INTRODUCTION

One of the main purposes of basic Physics and Mathematics courses is to develop the students' ability of abstraction and their problem solving skills. When these cognitive processes take place, the concepts involved must be fully understood. Although a regular student can reproduce the steps needed in order to achieve a given result, in many occasions the logical process is not clearly understood.

It is well known that motivation is a key factor in learning. However, not all the students are motivated in these areas and this fact may have an impact on the relatively high drop-out class rates occurring in many engineering courses.

II. THEORETICAL FRAMEWORK

Physics and Mathematics make sense when they are presented within a frame of reference that is meaningful to the student. Some researchers have found that gamification techniques can be used as an educational tool to attract and increase student interest [1–3]. In addition, gamification techniques have proven to be a good tool for improving average scores through practical activities [4–5]. Through the game, concepts come to life in a friendly context for the student, stimulating them to learn in a playful, attractive way and at their own pace.

III. DESCRIPTION OF THE INNOVATION

Several *apps* focused on education can be found on the market. For example, *Duolingo* [6] focuses on learning foreign languages, Quick Graph [7] helps to visualize curves in 3D, and Zoo Particle [8] is meant to learn elementary particles.

Up to now, the authors are not aware of the existence of a Physics and Math App displayed in Spanish aimed to promote the acquisition of basic concepts through gamification techniques. The novelty of our project, named *CocoGame*, resides on the usage of educational technology with gamification to enhance learning in Physics and Math suited for mobile devices (tablets, cell phones and laptops). The main objective is to foster the basic understanding of Physics and Math in order to develop and improve the students' ability to pose and solve problems by means of a solid comprehension of the related concepts.

CocoGame takes into account three main aspects: *a)* content design, *b)* graphic design and *c)* computational design. As of today, the content of the web platform is already underway. An interdisciplinary group of highly experienced teachers in the areas of science and programming from the Tecnológico de Monterrey, Mexico City Campus designed Physics and Math content taking into account gamification and Game-Based Learning elements. Other members of the team have also experience developing Web pages and Apps. Advanced students of Engineering in Computational Technologies were hired for the graphic and computational design of the platform. The material is currently uploaded onto a web platform and can be displayed 24/7 on mobile devices. This will empower the students to build his own knowledge in a flexible and attractive way.

Our hypothesis is that by means of using *CocoGame*, the academic students' performance will improve. The hypothesis will be tested through pre-test/post-test assessments in experimental and control groups during the Fall-2017 term.

IV. DESCRIPTION AND ELEMENTS OF THE GAME

Two main platforms, the teacher's interface and the students' interface, were programmed in order to run *CocoGame* in one of our private servers. The teacher's platform allows to upload and edit content admitting a variety of formats. It also keeps track of the players' interaction with the system, their current ranking and their *play* efficiency in terms of the percentage of correct answers achieved, number of final *stars* and earned badges (see below). Fig. 1 shows a screenshot of the teacher's platform login screen. On the other hand, the student's interface is where the actual game takes place. It is in this space where the students will be challenged about their comprehension of Physics and Math concepts.

So, what is the game about? It consists of *a) Universes*, *b) Worlds, c) Levels,* and *d) Items*. The universes developed so far

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are Physics and Math, and we are currently working to include the Chemistry universe as well. We have also planned a fourth universe, called *Random Universe*, in which the student may play in *practice-mode* answering items which have already been answered (either right or wrong) from the Physics, Math or Chemistry universes.

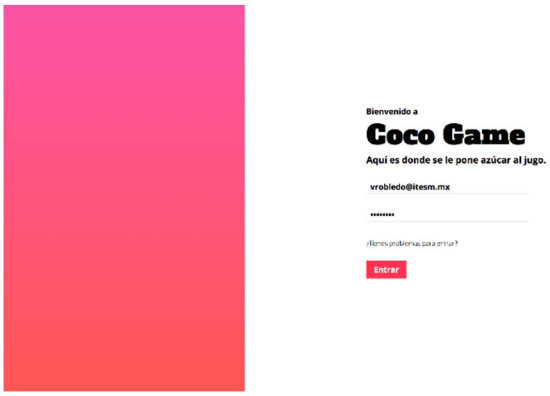

Fig. 1. Initial screen of the teacher's platform

The content is presented through a playful story of the main character, *Cocol* (a funny brain), who evolves through several stages of development (Fig. 2). Initially, *Cocol* is small, ignorant and without earthy possessions. As the user correctly answers the questions (progressing through the worlds and levels of the game), *Cocol* grows, acquires wisdom and may accumulate a number of possessions (see below).

Fig. 2. *Cocol*, main character of the game

Fig. 3 shows the entry screen for the student interface, the universes available so far and part of one of the levels of the Math Universe (*Roots*).

Each world corresponds to different course themes. The Physics universe contains the worlds of *Basic concepts*; *Vectors*; *Kinematics*; *Dynamics*, and *Work and Energy*. The Math universe contains the worlds of *Functions*, *Limits and Continuity*; *Derivatives*, and *Applications of the Derivative*. Each world (course theme) typically has about 5–10 levels, and each level contains about 5–10 items (questions) with different degrees of difficulty: *easy*, *intermediate* and *difficult*.

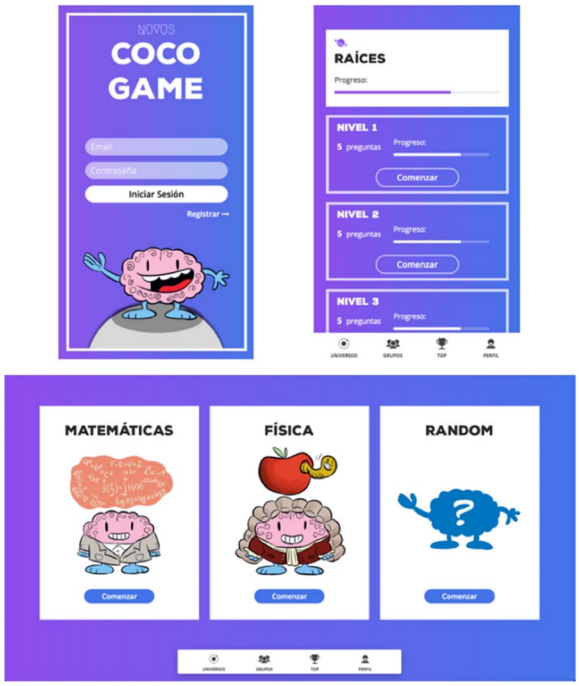

Fig. 3 Elements of the student interface

In the first user screen, the student goes through a self-registration simple process, logs in and chooses a universe and a world to start with. After a world is selected, the available levels within that world are displayed. For a player to move to the next world, *all* the levels within that world must be completed. The first level of a given world has a larger proportion (about 70%) of easy items as compared to intermediate and difficult items. As the student progresses to higher levels within the world, the proportion of intermediate and difficult items increases, so that the advanced levels have mostly difficult items. In order to pass a level, the student must answer correctly *all* the questions within that level, and the player has the option to repeat a level or world as many times as desired.

At the beginning of a level, the student starts with 3 stars. However, for every incorrect answer given, a star is removed. If the player runs out of stars and makes one more mistake, he/she must repeat the entire level. The stars retained in a given level cannot be used for the next level. However, they are included for his/her final score. In this way, the total number of stars is an indicator of the level of wisdom and efficiency attained by *Cocol.* At the end of a world, the stars owned by student can be exchanged for rewards, such as vehicles, pets or other earthy possessions (Fig. 4).

Additionally, as the student makes progress through the game, he/she can also win a number of points and coins that can be used later to buy hints for selected hard questions and earn badges (Fig. 5).

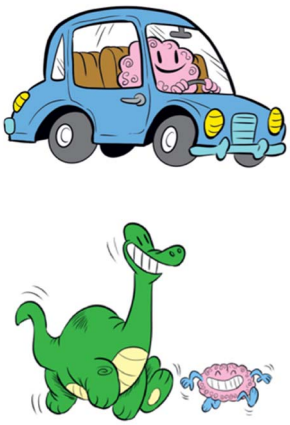

Fig. 4. Vehicle and pet for *Cocol*.

The game also contains Performance Records that show the relative position of the student with respect to the total number of active users.

Fig. 5. Coin and trophy for *Cocol*.

V. ITEM DESIGN

Each questions within a level includes the following metadata: *a)* Title; *b)* Topic tags; *c)* Author; *d)* Status (pending review, rejected or approved); *e)* Body of the question; *f)* Type of item (see below); *g)* Degree of difficulty; *h)* Hints and *i)* Support material (e.g. links to multimedia resources, videos, etc.). The types of questions already developed in the game are: *a)* Multiple choice; *b)* Fill in the blank; and *c)* Open field response (numeric or alphanumeric). For the numerical items, the system allows the professor to establish a margin for the error, either numerical or in percentage. We are currently working in implementing other types of items such as *d)* Drag-and-Drop; *e)* Word-search puzzles; *f) Hangman* and *g)* Crossword.

In order to give variety to the game, a given question from the items' pool can be adapted to be used in more than one type of item. This programming dynamics gives versatility to the game. In the case of open numerical responses, for example: The acceleration of gravity at sea level is ___ m/s^2 (correct answer: 9.81), it is necessary to indicate the number of significant figures to be used in the answer and the absolute or percentage error accepted for the given answer.

All items may include figures, charts, diagrams, drawings, words, numbers, and latex text or equations as appropriate. It is important to emphasize that the academic content is peer reviewed by professors of Tecnológico de Monterrey before being displayed in the platform for the students

VI. COMPUTATIONAL ASPECTS OF THE GAME

CocoGame was written on *Meteor*, which is based on JavaScript. Meteor allows the development of Apps that work properly on a wide variety of Internet browsers, as well as on mobile devices with iOS or Android operating systems. In addition, Meteor allows the update of the content of the application even after the installation on the mobile devices. JavaScript is a well-known language that easily allows the addition of several collaborators. The development methodology used was RAD (Rapid Application Development) since it allows the accelerated creation of prototypes that can be constantly discussed by the team members. In addition, RAD allows the subdivision of the project into modules. In our case, two modules were considered: *a)* the administration module, where the teachers handle the academic content of the game and *b)* the user module meant for the students.

The content management platform allows teachers to define and edit the different Universes and Worlds that will be available to the student as well as the design of the items to be used to construct the game levels. The platform design is meant to allow a given item to be used in multiple modalities as mentioned above, i.e. it can be used as a multiple choice question, or as part of a crossword puzzle. In order to reduce possible errors in the items, a peer review process was internally implemented. The author of a given question load it in the teachers' platform, and it has to be reviewed and validated by another teacher from the team. Therefore, the question can be accepted or rejected. If it is rejected, the suggested changes must be taken into account until it is accepted. Once the question is ready, it is displayed in the students' interface.

The student platform design is such that the student is free to choose a universe, world and level to start practicing (Fig. 3). The degree of difficulty of the questions within a world increases gradually as the student progresses within the level. The teacher/administrator has also the option to download the performance history of a selected subset of students. Even more, the teacher may ask his/her students to practice a specific world or level within the game in order to guide a study session and to monitor the progress of the students. A third option for the student is to play in the *Random Universe*, where he/she can review the material of any of the other universes that has already been answered by the student.

In any of the game modes, the system evaluates the questions automatically. For this, each question has associated at least one valid answer. It is possible to associate invalid answers as well that are displayed as additional options in a multiple choice question. There are two types of open answers: numerical and short texts. For the numeric type, the professor may set threshold values which delimit the validity of a given answer. For the text type, a preprocessing step is performed to make the answers invariant to capital letters and special accent marks.

The storage format of the information collected by the platform is JSON (JavaScript Object Notation). This information is managed by MongoDB, which allows a modification of the schema of the original data in case new requirements are identified by the team members and programmers in the future.

VII. Implementation process and evaluation

We are currently evaluating the use of *CocoGame* with our Physics and Math students in order to review the structure, graphic display, esthetic and functionallity of the user interface.

A Pre-test/Post-test methodology with experimental and control groups is planned for the 2017-Fall semester with engineering students from the Tecnológico de Monterrey, Mexico City Campus, taking Physics and Math courses in an attempt to quantifying the impact of *CocoGame* in our students' academic performance. The results will be published elsewhere.

VIII. Conclusions and future work

In this paper an educational-mobile web platform based on gamification techniques called *CocoGame* was presented. The web-app is designed to improve students basic understanding in Physics and Math at the university entry level. Universes, Worlds and Levels give structure to the adventures of *Cocol*, the main character of *CocoGame*. The items' format so far include multiple choice, fill-in-the-blank and open numeric and text questions. We are working to include other types of items such as crosswords, word-search puzzles and the well-known word-guessing game: *hangman*.

As the game progresses, the stars, points and coins are earned by the user and can be exchanged for earthy possessions. The innovation of the project resides on the fact that, up to is point, we do not know of any similar educational app in Spanish to address a solid comprehension of Physics and Math concepts. A Pre-test/Post-test methodology assessment tool with experimental and control groups is planned for the 2017 Fall semester in an attempt to quantifying the academic impact of *CocoGame*. Currently, this app is only available to Tecnológico de Monterrey students, but we plan to make it available for a greater public. We are currently adding content for the Chemistry Universe.

Interested researchers or students in the game, please do not hesitate to contact the authors. A promotional video of *CocoGame* can be found in *youtu.be/9Cm33-wbJQg*.

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