Project SIGMA - An Online tool to aid students in Math lessons with gamification concepts

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Abstract—This paper describes the project and implementation of an interactive online platform to aid junior and middle high school students in Math lessons and training for the Brazilian Mathematics Olympics of Public Schools (Olimpíada Brasileira de Matemática das Escolas Públicas - OBMEP). The system allows the learners to solve random generated problems divided in three main themes, which are: Arithmetic, Geometry and Combinatorial. The system aims to make the student solve a certain number of problems in order to understand the algorithms and logic behind them. It is also tied with gamification concepts to engage students in the proposed activities, since this method has achieved a high positive acceptability in educational area as a student motivator. The conclusions so far are the project and implementation of the Systems’ main modules and the validation of by Math Professors.

I. INTRODUCTION

The Olimpíada Brasileira de Matemática das Escolas Públicas (OBMEP) is an initiative promoted by the Ministry of Science and Technology (Ministério da Ciência e Tecnologia - MCT) and Ministry of Education (Ministério da Educação - MEC), realized by the Institute of Pure and Applied Mathematics (Instituto Nacional de Matemática Pura e Aplicada - IMPA) in partnership with the Brazilian Mathematical Society (Sociedade Brasileira de Matemática - SBM) [1].

This event focus on Math studies in public schools, and contribute to the improvement of basic education quality. Also it stimulates the improvement of teachers and contributes for the integration between public schools and colleges, scientific institutes and communities.

It is important an important event since Brazilian students had a critical position on the PISA (Programme for International Student Assessment) in Mathematics. In the last evaluation they achieved the 58th position, which occurred by the lack of basic education training [2].

Many methods were and are being created to ease this situation, one of those is the inclusion of games in educational methodologies, or game-based learning. Studies were conducted to prove the potential of those games in learning processes [3].

Some of those recent researches in the late years allowed the emergence of new techniques to improve a persons’ engagement. One of those is called Gamification which can be defined as the extraction of game elements and mechanics and its implementation in real applications, in order to improve a person or group commitment to a task [4] [5] [6] [7]. Considering the above we propose to build an interactive social web platform to aid students and teachers in Math lessons. This is done by helping students to accomplish Math challenges while they are engaged and learn at the same time. Also, it will store the user profiles in order to aid teachers to observe the main flaws of their students.

This paper is divided in the following sections: II explains the basic concepts of gamification, while III describes the project and its implementation while IV presents the conclusions.

II. GAMIFICATION

Gamification, according to [4] [8] [5] is the utilization of game concepts and mechanics outside its scope. It’s a motivational technique to improve and stimulate engagement, and can be applied in many areas from education, to health, fitness and business [6] [4].

This technique arose from the studies conducted to identify concepts and properties that make digital games so appealing to the majority of the population. In order to do that it is necessary to anatomize the game in its core.

According to [9], A Game can be defined as a system that induces emotional reactions in the player. Which uses it for the interactions and constant feedback. Which are also related to a set of rules that determine the challenges, those induce quantifiable outcomes inside the abstraction of a bigger system.

Those set of rules are generally related to the game elements, which according to [10] are some basic concepts that can be found within the system and be applied outside its main scope (Table I).

<table>
<thead>
<tr>
<th>TABLE I. GAME ELEMENTS ACCORDING TO [10]</th>
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<tbody>
<tr>
<td>Goals</td>
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<td>-------</td>
</tr>
<tr>
<td>Time Pressure</td>
</tr>
<tr>
<td>Novelty</td>
</tr>
<tr>
<td>Cooperation</td>
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<tr>
<td>Judgment</td>
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Table I demonstrate some concepts that are encountered within games. The lack and excess of those elements can impact in either a positive or negative way. The author [10] also explains that each one affects a different area.

A study used to support this theory, which also is being used in this work, is the one made by [11]. He describes the three pillars of a person’s engagement, as: Autonomy, Mastery...
and Purpose. Autonomy is the desire of people to have control over their lives.

As for Mastery, [11] describes as an improvement on personal satisfaction through challenges. Finally, Purpose is defined by the social interactions, performed by the subject, which provides meaning in life.

The elements from Table I can fit in those pillars. Judgment, Chances and Puzzles can be used in Autonomy. Progress, Recognition and Status can represent Mastery. While Social Pressure, Competition and Cooperation can be described in Relation.

III. METHODOLOGY AND RESULTS

The system consists in a web based platform where the students have access to various contextualized math problems. These were withdrawn from OBMEP’s questions database. Each one of them were generalized based on their specific properties.

In practice this means that problem statements are the same but the values and solutions are completely different. Which generates randomness. The system was implemented using CakePhP framework.

Methodology of Acquisition of the Problems

The system is divided in three major themes, which are also covered by OBMEP: Arithmetic, Geometry and Combinatorial. Each one of them covers a set of sub-themes, which are the divisions of the problems. Also, each main theme has three levels of problems, that affects the complexity and techniques to solve them.

In order to choose the questions that would be implemented within the system, we developed a technique to extract those problems from the OBMEP databases. This process was accompanied by Math teachers.

This analysis consisted in choosing the starting point of the selection, by making some questions, e.g Which theme should we start? What kind of questions should we analyze? How many questions should we choose at first?

After defining the starting point, it began the Selection phase, which was characterized by selecting the questions that could be implemented within the system. The process started by extracting questions that would fit some properties, e.g. questions from arithmetic theme from level 1 of OBMEP 2010 database [1].

Next were two parallel phases, which were the Classification of the sub-themes and the Exploration of the questions properties. The first one consisted in classifying the questions by its sub-theme. This allowed the creation of a knowledge tree of the Arithmetic section.

This tree also aided in the creation of the classification table (Table II) which was used as a pivot to classify the problems. This table was created with the aid of math teachers and covers 12 sub-themes of the arithmetic section.

Table II demonstrate the classification utilized to manage the questions. This representation was created based on the Arithmetic Tree and corresponds to the topics addressed by this thematic, but also can be utilized within other main themes.

The second mentioned phase, Exploration, consisted in finding the methodological properties of the problems and how the change of certain variables could affect the logic and resolution of the problem. This phase allowed the creation and selection of other problems by finding questions with similar characteristics.

After this phase, it began the Systematization of the problem. It consisted in extracting the main variables of the problem and expand it to a group of values that would fit its properties. This way we ensure the variety and randomness of questions with different results, however maintaining the same logic.

Finally, the final phase consisted in the construction of the algorithm that would be used to solve the problem. This was implemented through PhP Language scripts, in a module created to insert the questions.

Initially 105 questions were chosen to be implemented within the system. Those tasks are related to the Arithmetic tree and were divided in sub-themes, so the student may choose which subject he will train.

An example is question 114 from 2010 OBMEP database "Jorge’s walk on the park" which can be classified as [PP][ED][ART] 114. This question consists in making the student to use the Euclidian Division ($A = B \times Q + R$) algorithm, in order to solve it.

This problem has two variables that can be modified in order to alter the results without modifying the logic. These variables are the number of trees and the number of touches he does in each one.

In the equation used to solve this problem, $A$ is the number of touches, $B$ is the number of trees, $Q$ is the multiplier and finally $R$ is the remain that will be used to find the solution of the question.

The solution is defined by the starting point and the direction of the walk. However, apart from these modifications, the logic of the problem remains the same. The algorithm abstracted from this question can be seen on page 1.

The procedure seem on Figure 1 is the base for the final implementation of the problem and mini-game. All the questions return TRUE if correctly answered and FALSE if not, this is stored by the system in order to group the results for future analysis.
A. Modules

The system is divided in three main modules: System, Gamification and Professor modules. The first one consists in the main interface, implemented using a MVC model framework (CakePhp). It is responsible for the interactions (Controllers) with the user (Views) and the information stored in the databases (Models).

This module consists in the user login and profile visualization, and also interacts with the Professor and Gamification modules to extract their features. The user is able to select a main theme, its level and so its sub-themes. This will get a random problem to match the properties specified by the user.

As for the Professor Module, it is responsible for populating the questions database. It requires that the professors have a minimum knowledge on PHP programming language to write the algorithms. Those are stored in the Databases and are called via functions directly on the page.

The problems have individual statistics to determine the number of correct and wrong answers. Those are stored within the databases and may aid the professors to visualize the major flaws of their students. The user also have access to their own statistics, which determine the total problems that were made, number of correct answers of each area, achievements and so on.

B. System’s Gamification

The gamification of the system is based on the utilization of extrinsic motivators as points, levels, badges and so on, in order to stimulate intrinsic concepts as sense of achievement. Those concepts were implemented in order to make the system more engaging to the user and each one of them are connected in order to improve the user experience.

The system provides several kind of bonus, such as: badges and certificates of achievement (documents that give them proficiency on that area). Users can have access to different chat rooms and levels of forums to discuss new problems with other users in the same level. We are working now in an army classification beginning with a rookie to general.

These features were created to encourage the students to try to become an expert on each area of math and to make them more competitive and collaborative (there are badges to students that help their friends and colleagues). The selection of the gamification concepts are divided in the three areas defended by the author, and described below in the table III below:

<table>
<thead>
<tr>
<th>Table III. Gamification Concepts within the System</th>
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<tbody>
<tr>
<td>Pillar</td>
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<tr>
<td>Autonomy</td>
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<tr>
<td>Competence</td>
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<tr>
<td>Relation</td>
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Those may also serve as an evaluation of the Gamification module, since the overview will show the most common and uncommon achievements in the community, allowing the creation of others and so on. Also it is intended to put a questionnaire to validate the user experience within the system.

IV. CONCLUSIONS AND FUTURE WORKS

This paper described the implementation of a system to aid students in math classes and in the preparation for the upcoming OBMEPs. By the utilization of the system it is expected that more students achieve better results in the upcoming events and in classes.

The main objective was achieved, since we completed the System, Professor and Gamification Module. The application is being prepared to be used with students that are preparing for upcoming OBMEP events and also students that have difficulties with Math lessons and are willing to improve their skills in solving math problems.

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REFERENCES


