FracPotion: An Open Educational Game to Teach Fractions in Brazil

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Abstract. The areas of Science, Technology, Engineering and Mathematics, called STEM careers, are important fields of knowledge for society nowadays. Among the basics subjects of these careers is Mathematics, but many young students present difficulty to understand very basic mathematical concepts and logical thinking activities. This learning process is very complex and demands a lot of motivation by part of the students. In this sense, educational games can act as an interesting and stimulating helping tool for them. In Brazil, the levels of proficiency on rational numbers in their fractional representation presented by students aged between 9 and 12 years, in general, are low, mainly because in local culture the fractional representation is not common at the daily activities. The educational games to teach this topic in Portuguese are few, so it has motivated us to develop a game to teach fractions entirely in Portuguese language, but able to be adapted to other languages of the region, like Spanish. In this paper, we present such a game, called FracPotion, developed as an Open Educational Resource to teach about fractions to children. The game was experienced by a group of students in an elementary school at São Paulo city, Brazil, and the preliminary results were positive.

Keywords: Open Educational Resources, Open Educational Game, Mathematics, Fractions.

1 Introduction

STEM (Science, Technology, Engineering and Mathematics) careers are increasingly becoming each time more relevant for contemporary society. Some countries are concerned if they really can produce enough skilled workforce on STEM careers to compete at the global market level for the recent future [1]. Some of the basics skills to be developed in the context of STEM are on Mathematics, Physics and Programming, but many young students present difficulty to understand very fundamental mathematical concepts or to develop logical thinking activities [2], this one related to the broader concept of Computational Thinking [24]. If we want to prepare our children and teenagers to have possibilities of work in future STEM careers, we should offer more didactical and motivational tools and challenges to them.

According to [3] we should not to force young students to learn with the same methods their grandparents have been exposed to, because traditional school learning based on predefined sequential curricula cannot completely meet the requirements for the 21th century children, so modern tools should be applied to complement these current requirements. Learning processes are inherently very complex and demand a big amount of motivation by students. Thus, naturally motivating tools like educational games can be interesting as vectors of stimuli for students [4]. According to [5], videogames could be used as support for several pedagogical aspects such as motivating students and providing attractive and sometimes effective educational tools.

Mathematics, as any other broad field of knowledge, has many sub-topics that makes virtually impossible to develop a sole digital game to cover all subjects, so it is appropriate to choose some specific topic to plan the design and application of educational games. In Brazil the mean level of proficiency in Mathematics, in general, presented by students aged between 9 and 12 years, is low; this situation is more serious when they comes to learn some topics that are not common in their daily activities, like rational numbers in their fractional representation. Different from its neighbors in Latin America, in Brazilian culture the fractional representation is not a commonplace – even ½ is often represented in its decimal form (0,5 – with comma).

Regarding this, the development of a game about fractions would be of great value to complement the learning of this topic, especially if the game offers some facility of adaptation by teachers. Therefore, in this paper we present an Open Educational Game [25] called FracPotion to help students about fractions. The game was applied to 18 students of an elementary school at São Paulo, Brazil, and the results were positive.

2 Learning Fractions: The Brazilian Reality

The National Basic Education Assessment System (SAEB) of 2001 [6] reveals that only 35% of Brazilians students were able to solve simple problems involving fractions; many of those that failed had problems with the part-whole relation, which is considered the most basic concept in this topic. The São Paulo State Performance Assessment System (SARESP) in 2005 [7] revealed that only 37% of students answered simple questions regarding such a topic. The results of the Programme for International Student Assessment PISA (2012) [8] showed that two out of three students do not know how to work with simple operations involving fractions.

A survey recently conducted by the International Student Assessment Program in (2015) [9] showed a drop in scores in the three areas assessed: Science, Reading, and Math. The drop in scores also reflected Brazil's drop in the world ranking: the country ranked 63rd in science, 59th in reading and 66th in Mathematics. The Figure 1 shows the results of proficiency in Sciences, Reading and Mathematics of the Brazilian students in elementary schools, according to OCDE and PISA 2015 [9].

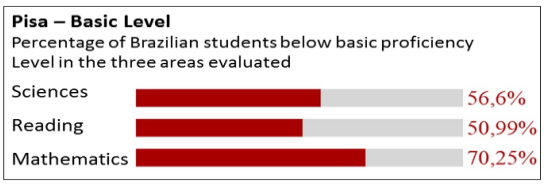

Fig. 1. Results of proficiency in Sciences, Reading and Mathematics of the Brazilian students in elementary schools, according to OCDE and PISA 2015 [9].

There are three very important aspects to the practice and learning of fractions [10]: first, the practical aspect, in which fractions in their different representations, appear, often in several situations related to the expression of measures and quantities – this fact highlights the need for extension of the set of natural numbers. Second, the psychological aspect, since working with fractions appears as a privileged opportunity to leverage and expand mental structures necessary for intellectual development. Finally, the Mathematical Perspective aspect, since it will be precisely the first studies with the fractions that will ground more complex ideas such as operations.

We believe that an Educational Game that presents fractions and give player the task of reorganize them can offer experiences that address the three aspects mentioned by [10]. Since learning fractions requires a reorganization of numerical knowledge, such a game would allow for a better understanding of numbers than it is commonly gained through experience with natural or integer numbers [11].

About the third aspect explained by [10], many authors show different approaches to the mathematical perspective in the teaching of fractions. According to [12] the focus of mathematical programs should be on fractions as quantities, to allow students to make a correlation with their previous knowledge of natural numbers as quantities. [13] suggests that teachers need to introduce a variety of fractional interpretations for students, as students whose fraction learning was previously focused on regular fractions of tend to have an impoverished understanding of the rational numbers. In [14] there is an experiment with elementary school students that analyzed how students think to determine larger or smaller fraction values and make the order of fractions conform> This experiment was performed with pieces of paper, but it could be easily achievable as a digital game, which would allow player to interact with the fractions trying to reorder them.

3 Digital Educational Games to Teach and Learn Mathematics

3.1 Educational Games Overview and Applications to Teach Mathematics

Today we live in a world that offers many technology tools for children and young people; usually these young people's first contact with electronic equipment happens through Digital Games [3]. These can be defined as engaging, interactive environments that capture player attention by offering challenges that require increasing levels of dexterity and skills [15] [16].

Many teachers believe that regardless of whether a digital game has or not some educational purpose, it could contribute to psychomotor skills, development of analytical skills and computational skills of the player. This is mainly due to the difficulties faced during the game, the need to create new strategies (when strategies used before are no longer good), the pressure to develop strategic thinking, among other common aspects.

3.2 Related Works

Educational games could be effective learning resources, mainly when applied to courses such as Mathematics or Science, often considered as difficult, abstract courses. They also have the potential of influencing students' social and daily life, affecting their behavior with colleagues [18]. However, many authors – like [26] and [27] suggest that educational games need more empirical evidence of effectiveness, requiring more evidences in this field. According to [20] the research field of educational games still has a limited quantity of empirical evidence about the effectiveness of games, especially in the domain of Mathematics. Some other works, like [19], bring stimulating results regarding to the use of digital games in the specific topic of fractions.

In [21], an educational game called "Animo Math" was developed to help 5-7 years old children to learn Mathematics. The game has five levels with different difficulties, beginning with calculus that uses only single digit numbers (0-9) to teach/reinforce addition and subtraction operations; the other levels present more digits and different difficulties in calculus. In this work, there were expected the following four benefits in his game:

1. Make children more interested in positive learning in Mathematics.
2. Gain more of children's attention by using cartoon animations and fun sound effects.
3. Enable children to see the fun of Mathematics.
4. Parents perceive how to use modern digital technology and computers for children in mathematical learning.

In [20] an educational game was developed to teach about decimal numbers. In this game the students are introduced to a group of some fantastic characters that act as guides to Decimal Point Game and encourage students to play, congratulating them when they correctly solve problems. The game is composed by several mini-games inside a kind of Amusement Park. However, the game does not present numbers in factionary format. After playing a mini-game and correctly solving the problem, the student was prompted to explain his or her solution, by choosing possible pre-listed explanations from multiple-choice options available.

4 The FracPotion Education Game

FracPotion is a 2D educational game that was created for elementary school students. It is expected to evaluate whether students find the game funny and whether they can better identify, practice and understand educational content about fractions.

For the game to be better accepted by students, a narrative was created that justified the need to work with fractions in the game. In this sense, a wizard is proposed as a character since he employs fractions to combine potion ingredients that allow player to have progress in the game, when potions are properly created with the correct fractional quantity calculations. The background history to support the narrative follows:

"The game takes place in a kingdom called Camelot, ruled by Arthur. This kingdom is being threatened by a wicked witch named Morgana who, along with an army of wizards is heading toward Camelot to defeat Arthur and rule over humanity, but with the help of Merlin and his apprentice Arthur intends to defeat her with Magic potions.

For the creation of potions, it is necessary to define the right dose that is in the form of fraction and thus create the potion to defeat Morgana and save the kingdom from destruction."

4.1 Game Overview

The game FracPotion is a simple adaptation of the classic history of King Arthur and his knights, where to defeat the villain Morgana, the player (as an apprentice) will have to hit the right amount of ingredients to complete the potion represented by fractions. This kernel of the game is explained (in Portuguese) on screen of game illustrated in Figure 2.

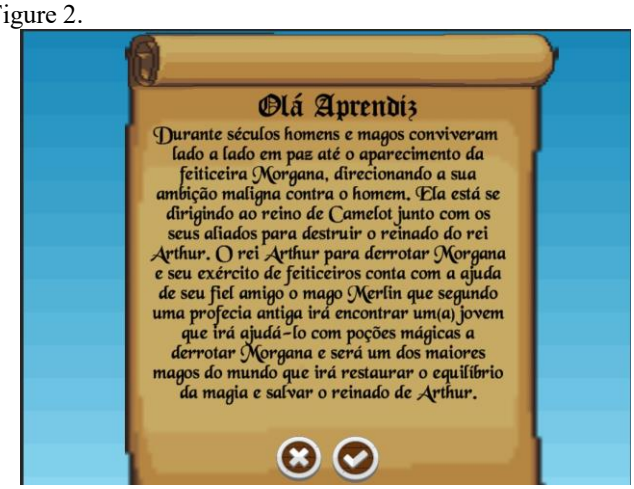

Fig. 2. Screen explaining the story behind the game.

Players are not punished for their mistakes, they only earn stars according to the number of attempts they used to reach the required amount of ingredient that was thrown into the cauldron. Figure 3 is an exhibition of the first level of the game. Contains a question the player must answer to complete the potion. In Figure 3 we can see the score markers, error markers and the elapsed time. The character is the wizard in the lower right corner of the screen and the alternatives A, B, C and D are the possibilities to complete the potion in the cauldron.

Fig. 3. First level of the game

It must be noted that, even though the game was conceived in Portuguese language, it can be easily translated to any other language, as well as it is possible to modify most of its aspects, given that it was designed as an Open Educationa Resource. Source code is available on GitHub and is made available under open source license.

4.2 Development of the Game.

The Game uses a 2D view and was developed in JavaScript and WebGL to facilitate the visual work that forms the look-and-feel of the game. Game's target audience is composed by students who want to discover or review contents about basic fractions.

Cocos2D-x is a multi-platform framework for developing games and graphic applications [22] – the "x" letter in the name of the framework means that it can be changed by one between several languages supported; in our case, the chosen language was JavaScript (JS). This framework is a branch of another framework with a similar name called Cocos2D, which is focused on development for Apple devices running the IOS operating system. The big advantage of Cocos2D-x was to bring improvements to the then Cocos2D:

- It has a simple but also very powerful phase creator.
- Accessible through all major operating systems.
- Make it possible to publish games, for various platforms such as Windows, Mac OS, Linux, Android, iOS and also to the Web, in any HTML5-supported browser.
- Possibility to create your applications through various programming languages, such as C++, Lua, JavaScript, Objective-C, Swift, C#.

Figure 3 exposes de Cocos2D-x framework used in this paper.

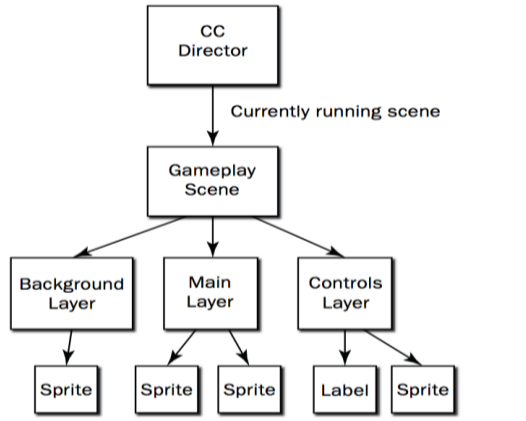

Fig. 3. Framework hierarchy

The way the framework works is by using the concept of a director and scenes, being each object on the screen a node in a component tree. Everything that will be drawn is controlled by a class called *CCDirector*, where it has the ability to modify the order of how components will be drawn and also change the game scenes, being responsible for defining the initialization of the components that are requested by the framework calls. The Cocos Creator tool tends to hide most of this complexity.

Cocos Creator is an editor that works on top of the Cocos2D-JS framework, assisting in the development of the graphical application whatever it is, showing the properties of the components, also providing a preview of what the game scene will be at the moment that it is loaded and a way to graphically manage the files and scripts that will be within the game. The scenes within Cocos2D-x are the most basic component of each game window, within each scene, will be all the components, effects, texts and images of the game being then managed by the Director.

5 Evaluation Of The Game And Educational Content

For the evaluation of the game FracPotions, an experiment was carried out with elementary school students. As we wanted to evaluate the experience of the children under a qualitative approach, we studied two different frameworks in the evaluation process. The first one was the generic ITU BT500 assessment (https://www.itu.int/rec/R-REC-BT.500) –and the other one was the MEEGA+ model [23]. After we have analyzed these two assessment models, we have chosen the second one, so the MEEGA+ model was used to evaluate the quality of the game and educational content, since it is directly focuses in educational game evaluation instead the generically approach of the ITU BT 500 for all type of software.

5.1 Experiment

The experiment was carried out with elementary school students. The participants of the research were 18 students and the criterion of choice was that they already knew the basic concepts of fractions learned in the classroom. The profile of the students of the experiment presented a mean age of 12 years, there was a balance with respect to gender, but the girls slightly predominated on boys; 92% of volunteers make regular use of digital games - 47.6% on a daily basis and 9.5% weekly. Players first had an experience of interacting with the game, without the help of any instructor. Soon after, they answered a survey about the aspects of the game, involving the visual characteristics of the game, the interface, the easiness that the game possibly presents and other aspects of usability of the game. In addition, the survey had extra questions about the educational content presented and its relationship with the game, as a way to verify if the game met the educational purpose regarding fractions. The students answered the questions using five possible responses in a Likert-like scale (Too little, Little, Neutral, Very, and Very much).

The questions to evaluate the educational content of the game were:

1) How motivated did you feel to learn about fraction with this game?
2) Did you learn about fractions with this game?
3) Would you recommend this game to a friend?
4) Would you rather learn fractions using this Game?
5) Did you feel challenged by this Game?

5.2 Results Obtained

The combination of texts, colors and sources were pointed out as good combination and consistency by 62% of the interviewees and the other 14% answered neutrally (neither agree nor disagree). As for the game being intuitive and easy to adapt 30% agreed with this aspect and 43% responded with neutrality. As for the easiness to understand rules, 53% judged them easily understandable and the other 28% responded with neutrality. About the questions regarding the educational content, the students have answered to the question (1) positively or neutral 61% (11 students); question (2) have 56% of positive answers (10 students); third question (3) had 94% of positive or neutral answers (17 students); question (4) 78% (14 students); and question (5) had 67% of positive or neutral responses(12 students).

6 Conclusions and Future Work

The teaching and learning processes in the field of Mathematics require an important effort on building knowledge over a very abstract body of knowledge, but with many practical applications in real-world situations. Fractions, for instance, tend to represent an extremely abstract concept, mainly when local culture do not make regular use of this kind of representation in common situations – which is the case for Brazilian culture, which have adopted the floating point decimal representation in

detriment of the fractional one. Tools that help to stimulate students to keep motivational aspect when learning such subjects are potentially useful to these process.

This paper presented a game designed to support students to learn or revise some basic fraction concepts. Regarding the group to which this game was applied, the players/students showed interest in game's subject and they reported to have enjoyed the learning process supported by the game. However, the results point out that more research is needed in order to improve the game itself and to apply it in other study groups. Further work includes the development of other games for different subjects in Mathematics and other STEM areas. The current game is in its beta version; as improvements, new phases are to be developed with other types of fractions and operations, as well as the translation and adaptation capabilities of the game as an Open Educational Resource are to be tested.

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