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# Presenting the key ideas of fractions through MathFractions: a Game Based Learning

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**Abstract.** This paper describes a Game Based Learning tool to teach fractions. It was designed for children from 6 to 10 years old. It was developed considering the six facets framework to serious game. For the purpose of the study, 66 videos recorded were analyzed. On the other hand, the game was played by 34 students and it has been observed that 76% of them were able to complete three activities without problems, 24% of them completed only one or two activities.

**Keywords:** serious game; fractions; learning; math learning; games.

## 1 Introduction

There are changes necessary to implement in classrooms the usage of new ICT [1], the first one is to rethink the pedagogical practice in classrooms. It is necessary to research on the influence of digital games on learning, the importance of virtual learning environments in distance learning and the use of ICT [2].

In mathematics, fractions are one of the basic concepts in which learners present difficulties in their understanding. The points as the most frequent problems in the fractions learn are: a) the learners focus on the counting of parts prioritizing the number of parts and not the relation between the part and the whole; b) do not work with fractions larger than unity; c) there is no emphasis on the ratio number of parts and total size; d) fractions are not represented in the same scale; and e) comparing heterogeneous fractions [3, 4]. Some studies have shown that teaching with computer tools have better results than teaching using only verbal communication. It is also

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relative effectiveness of Video Mediated Instruction and Classroom Demonstration Technique on the performance of students [5–7]. In mathematics, many concepts and processes could be linked to visual interpretations, the reason why researchers used the potential of visualization and simulations in teaching [8, 9].

## 2 Related Works

Sommerfeld et al. [10], investigated the effects of design in fractions games, the goal of the study was to contribute to understand how particular types of digital games can support student learning and engagement. It was focused on commercially available educational apps that focused on similar content (fraction comparison and equivalence) but represented extremes in how game-like they were (games vs. worksheets). Third-grade students ( $n = 95$ ) worked on the apps for an hour in their math classrooms. Students performed equally well on a paper and pencil assessment, but students' enjoyment of the games was significantly higher. Student interviews indicated that students who played the games noticed the mathematics content in the games, sometimes linking it to the game mechanics, noticed the relevance of the game for the assessment and talked about enjoying the games. Findings suggest that exploratory games that implicitly support mathematics knowledge can improve students' math knowledge outside of the game context and improve student engagement.

Sevinc and Brady [11], investigated a tradition in mathematics education research which produced a genre of activities known as model-eliciting activities. They show two story-based model-eliciting activities aimed at kindergarten and first-grade (K-1) students' development of length measurement and an estimation of area measurement. The study highlights not only that young learners were capable of developing models on numbers representing length and area but also that engaging story narratives and parallel whole-class and small-group activities were the main resources to support the model development of young learners.

Dube et al. [12], they reviewed the published research papers indexed in databases such as Scopus, Web of Science, Google Scholar and others. The focus of searching was the use of tablets as elementary mathematics education tools. The goal of this study is to discuss whether tablet computers are useful for mathematics learning. The three more important tasks were: engaging children with mathematics, improving children's attitudes towards mathematics and improving children's mathematics achievements.

## 3 The six facets of the game design

Marne et al. [13] developed a non-sequential and flexible framework with 6 facets of serious game design. These facets were adapted and used in this serious game.

a) *Pedagogical Objectives*

Learn fractions  $1/2$ ,  $1/4$ ,  $3/4$  with a visual approach

b) *Domain Simulation*

The game was designed considering the student's context (culture aspects, geographical sceneries, society thinking). For example, the cultural thinking of a child from the mountain range of Peru (rain, mountains, clouds) and different to the cultural thinking of a child from the country of Brazil (trees, rivers, animals)

c) *Interactions with the Simulation*

Considering the mathFractions with all models (it is possible to use only one or more game models). The learner starts the game selecting the flag of his country, to select automatically the language and the context (Peru, Brazil, USA or France), as shown in Figure 1 (C).

d) *Problems and Progression*

The problem means that, the game has 9 options to solve problems, and they are grouped in 3 sectors: *Quadrilaterals* (filling quadrilateral blocks to pave the floor), *Circles* (representation of circles over the Cartesian plane) and *Fractions comparison* (visualizing the equivalence between two fractions). The progression means that each selected option of the game has 5 difficulty levels. The progression is from the easiest level to the difficulty level. Additionally, the game has 3 options to play: add (right arrow), subtract (left arrow), and combine add and subtract operations (left and right arrows)

e) *Decorum*

The game uses computer animation approach to engage the student's motivation.

In addition, when student completes correctly the task, there is a winning sound and icon representation, and when the student fails the task, there is a sound indicating fail and the correspondent icon representation, as shown in Figure 1(D).

f) *Conditions of use*

Students from six years old on could play this game. Most of the time, the game does not need assistance from the teacher or high ICT skills, but maybe young children need an explanation about the rules of the game. Only one player could play the game, it is not multiplayer.

## 4 MathFractions Design and Implementation

The game was developed considering the six facets methodology [13] and designed mostly for children from 6 to 10 years old. The game has some flexible characteristics of configuration for the user: the language selection, the image and the sound could be contextualized according the country. In addition, each level has a progressive difficulty. The software was developed using some tools like HTML5, JavaScript, Mysql, and phaser.io framework. Currently, the mathFractions series game are hosted under the URL <http://educaticos.org/mathfractions/>

The software was developed by undergraduate students of the Academic School of Computer Science at the National University Micaela Bastidas of Apurimac. The agile methodology of extreme programming was applied, in which the User Stories were created and then the programming tasks were assigned to programmers. It was very important to have graphic designers to create the scenes, the characters, and the images of the game; also, sound designers were needed to create the different sounds of the

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game. The tests were carried out by the programmers (alpha tests) and later by the children who collaborated with the project (beta tests) and after the corrections. Both tests allowed corrections and improvements to the software. The software game is multiplatform (Windows, Linux, Mac), multilanguage (English, Spanish, French) and easy to maintain.

## 5 Evaluation and Analysis

Initially, evaluations were made to the software product, through 5 children 10 years of age, this allowed us to improve the software and served as a pilot test before formally launching the product; then, two types of evaluation were carried out: evaluation by children and evaluation by video recording analysis.

**Analysis of children's playing.** This game was tested by undergraduate students, From January-2016 to October-2016, the system registered 34 children from 2 different schools; they acceded remotely to play the serious game. They played on freely, but their teachers recommended to follow the interface order (first is the top leftmost, the last one the bottom right). Considering the game model used, 75% played filling quadrilateral blocks on the floor, 19% played the representation of the circle on the Cartesian Plane, and 6% played the equivalence between two fractions.

**Video recording analysis.** The software was evaluated by 29 math prospective teachers (enrolled in four years graduation program to math teacher preparation) of the Institute of Mathematics and Statistics of the University of São Paulo. They worked in one session of about half an hour with mathFractions, each student with an individual computer desktop. There was no explanation about the software; they only received the Web address where the game was hosted. Previously free screencast software was installed in every computer of the laboratory (the *RecordMyDesktop* to Linux/Debian). The teacher and two assistants watched the group and their screen during the working session were registered in the video. A total of 66 videos were recorded, since some of them had no experience with *RecordMyDesktop* software, starting it more than once.

## 6 Conclusions and Future Work

This Game was developed to enhance fractions teaching and learners comprehension of the fraction concepts, directed to children from 6 to 10 years old. The tool was developed under the six facets framework to design serious games. The software is hosted and available at <http://educatic.org/mathfractions/>. In this interface and didactical evaluation of mathFractions 66 screen sessions were recorded and analyzed. It has been observed that: 76% of master degree students were able to complete three activities without problems; 24% of the students completed; and 24% of them completed only one or two activities, probably because they did not read the instructions correctly or did not recorded the activity completely.

In addition, we analyzed others 34 children that used mathFractions, indicated by 2 math teachers in 2 different schools in Peru and Brazil used the game, 75% of them played filling quadrilateral blocks on the floor, 19% played the representation of the circle on the Cartesian Plane, and 6% played the equivalence between two fractions.

For the future, the tool will be applied in real class sessions environment and will be measured the qualitative punctuation obtained by the students.

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