A BROWSER-BASED EDUCATIONAL GAME WITH ADAPTIVITY

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Abstract

Recent reviews have shown that the use of educational games during the learning procedure indicates significant growth. Browser-based games are one type of educational games. In this paper, an online educational game concerning arithmetic in elementary school is introduced. The game consists of a main platform and several mini educational games. The main target is to explore several locations and retrieve various items by solving math games. The students' answers define the difficulty level of the educational mini-games and generate error diagnosis. In this way, student knowledge assessment is performed and identification of possible mathematical weaknesses is obtained.

Introduction

Computer games play a significant part, not only in children's life but in adolescents' culture as well (Virvou, Manos, & Katsionis, 2008). The average time a person spends playing computer games during a regular school day is two hours and a half (Mysirlaki & Paraskeva, 2007). On the other hand, studies indicate that use of educational games has been dramatically increased (Coştu, Aydınb, & Filiz, 2009). Educational games' main objective is to assist students in learning a skill while commercial games aim to entertain. Studies have shown the combination of education and digital gaming may positively influence on students' thinking as they increase the feeling of fun while learning (Najdi & Sheikh, 2012). They can capitalize on students' enthusiasm and serve as a motivation for their learning (Polycarpou et al., 2010).

Browser-based educational games are one type of educational games. A browser-based game is a computer game played over the Internet using standard web technologies. The games are often free to play and do not require any client software installed apart from a web browser. Therefore, they are usually more accessible and affordable for the students. However, only few studies are encountered on the use of browser-based educational games in literature (Coştu, Aydın, & Filiz, 2009).

Researchers state that educational games can be used in subjects such as science, math, medicine, language learning and problem solving (Bayirtepe & Tuzun, 2007). In particular, it is noted that computer games are strong motivational tools for math lessons. This is a very important observation if someone takes into account the fact that many students often perceive mathematics as an unpleasant subject (Sedig, 2008).

A subject that can be associated with educational games is arithmetic.

Findings have shown that fluency in the basic arithmetic skills of addition, subtraction, multiplication, and division contribute to help students to improve their skills in mathematics (Sahasrabudhe, Shah, Thakkar, Thakkar, & Iyer, 2012). Fluency in math can be obtained by giving students the opportunity to practice continuously.

Moreover, researchers have proposed encompassing adaptive features to the development of educational games (Peirce, Conlan, & Wade, 2008). An adaptive game may be used to examine and determine students' knowledge levels. It can also identify students' possible weaknesses on specific problem types and help them overcome them. The game can adapt to students' needs and provide valid assessment information to students and teachers.

In this paper, we present a browser-based educational game that is associated to the context of arithmetic. We have implemented a user-modeling component that determines the knowledge level of students and, therefore, adds adaptive features in the game in order to help students overcome their difficulties in specific arithmetic concepts.

Related Work

As mentioned earlier, browser-based educational games are easily accessible by students. The TTNetvitamin case is a browser-based game that is associated with the context of mathematics (Coştu et al., 2009). The findings of the study state that using educational games in mathematical classes may help students to understand the topic better.

On the other hand, Diego Zapata-Rivera implemented the EM ABLE (English and Math ABLE) game that incorporates the feature of adaptivity (2010). The findings of the corresponding study showed that students enjoyed interacting with the game while the adaptive features included in the game helped teachers to assess students' performance.

Furthermore, the educational game Math-City is related to the context of arithmetic and its main objective is to supply students' the opportunity to build their own city while practicing mathematics concepts in primary education (Polycarpou et al., 2010). Teachers provided positive feedback and pointed out that they would like to use educational games as an additional medium to their teaching methods.

Each game had positive results due to different features. TTNetvitamin case is a browser-based math game, which means that students with different computers and operation systems can access it easily. EM Able is a math game as well. It may not be a browser game but it contains adaptive elements that may provide teachers with valid information about students' performance. Finally, Math-City is a suitable game for students in primary school who would like to practice in the domain of arithmetic. It's not browser-based or doesn't have adaptivity, but through the process of building a city with buildings and dealing with energy concepts while practicing in arithmetic, it has a positive influence on students, as it is an appealing and motivational game.

The features described above have positive results during learning processes due to different reasons for each one. We implemented an educational game that combines all these features in one game. It is a browser-based game, easily accessible to any computer with Internet access. It encompasses a student-modeling component and an error diagnosis system that contributes to the integration of adaptivity in the game and determines students' weaknesses. Lastly, the game's educational subject is arithmetic in elementary school and its main objective is to be used by students and teachers as an enjoyable tool for understanding better the concepts in arithmetic.

Overall Description of the System

The game we present is a browser-based educational game concerning the domain of arithmetic in primary school. It is divided into two sections. The first one is the main platform of the game, which is independent of the educational object that accompanies the game. The main scenario of the game is based on this platform and can be changed dynamically. The second category encompasses the educational object, which in our case is mathematics in elementary school. This section accommodates various small educational games that should be resolved by the student in order to continue the game at a faster rate. In this paper, we describe main platform's features and emphasize the depiction of an arithmetic puzzle game. Both main platform and mini puzzle game incorporate the user modelling process and adaptive characteristics.

The Main Game Platform

The main game begins by requesting a user account creation. The registration process presents several fields that have to be filled in by the student. These fields include student name and gender, a password and information relevant to his/her knowledge level in addition, subtraction, multiplication, and division. If a student has already an account, s/he may simply login to the game. When a user signs in, at the left column of the game, there are information and attributes associated with the player's account as illustrated in Figure 1. Information includes level rate, experience points, experience points needed to raise level rate, virtual money, current energy points and maximum energy points. Each attribute affects directly the game flow.

Figure 1. Student's attributes are presented on the left side of the screen. On the right side, a welcoming message is displayed.

A horizontal menu is located on the header of the game interface. This menu helps student to navigate through several game sections. The main platform is divided into the sections of maps, food, collections, tutorials and game. The map section provides each player a list of maps. Players can use virtual money and buy maps. Furthermore, the availability of particular maps requires a minimum level threshold. As soon as a student raises the corresponding level to a value equal or larger than a specific rate, the relevant maps can be obtainable.

The food section presents a list of food that each player possesses. Each piece of food is related to a particular amount of energy points. Food consumption raises a student's energy points by the corresponding amount. The addition of food rate to student's energy points may not result into a value bigger than maximum energy points.

Moreover, the third section named "Collections" provides a list of the items that students have already obtained. The items are grouped into the corresponding collections. Each time a player retrieves an object, the relevant collection is unlocked and player can see all the items that are necessary in order to complete the collection. Items in green are already in the student's possession. The player's objective is to find the remaining items and secure the collections. Each collection consists of five items of the same type. For example, the clothes collection includes a hat, a shirt, a jacket, pants and a pair of shoes. Another collection contains vehicle types such as a car, a motorbike, a van, a bulldozer and a scooter. After the completion of a collection, a player can secure it and gain additional points. The collections section is illustrated in Figure 2.

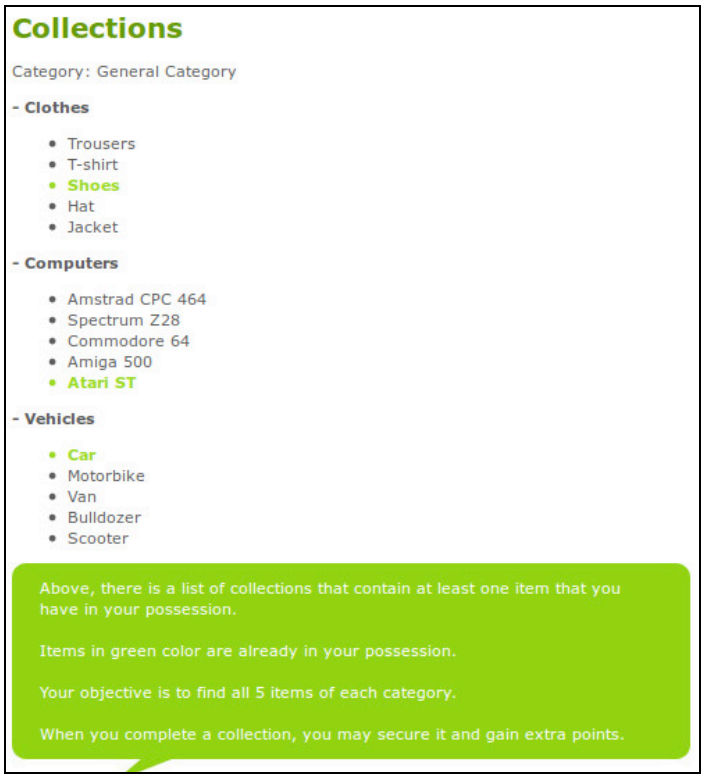

Figure 2. Collections of items list.

The link "Tutorials" of the horizontal navigation bar provides a list containing tutorials concerning specific cases of addition, subtraction, multiplication and division. All tutorials have game forms and guide student step by step in order to solve the exercises. In the case of addition, there are lessons about adding one-digit numbers, adding numbers without extra and adding numbers with extras. Similarly, in the case of subtraction, students may study how to implement a subtraction between one-digit numbers, or exercise in subtracting numbers with or without extras. Finally, students may seek tutorial guidance regarding multiplication between one-digit or two-digit numbers and division.

A significant feature of the tutorials section is a supplement list that suggests to each student to study particular tutorials depending on the mistake types made during the game play. If a student has made mistakes related to addition numbers with extras, the application suggests the student study associated game tutorials in order to understand the way similar additions are solved.

The last list item in navigation menu is named "Play." When students click on this link, the application leads them to the main game as shown in Figure 3. Initially, the game presents an isometric map depending on the selection that was made students in the maps section.

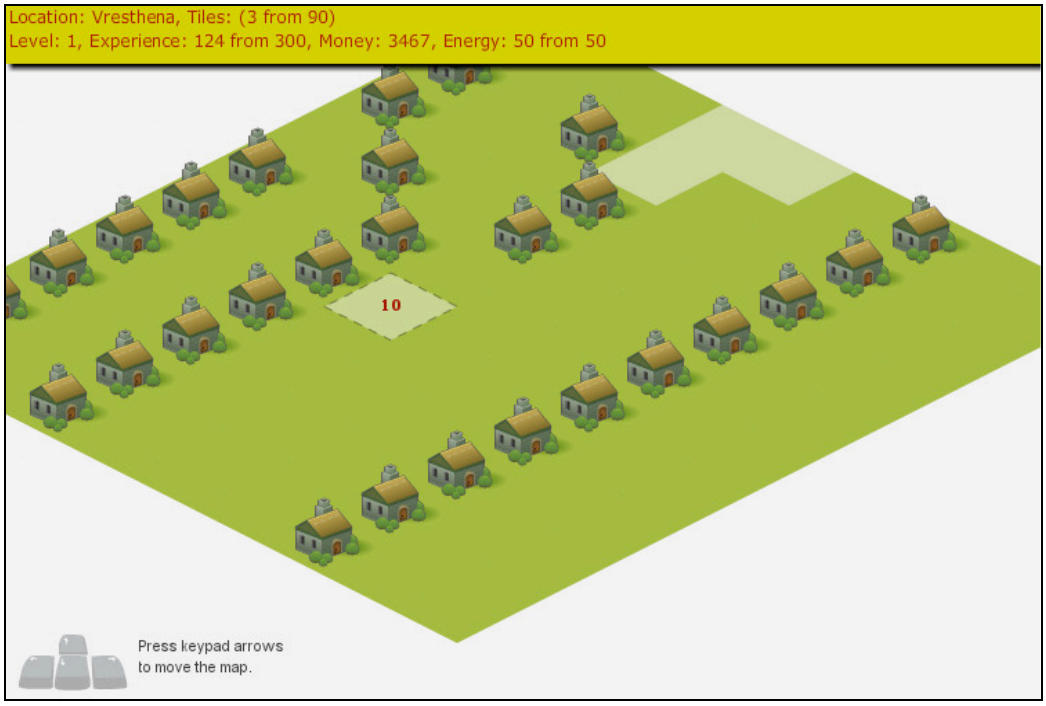

Figure 3. The main game screen.

On the top of the game screen, there is feedback regarding current statistics about user's profile, such as the current searching location, level rate, experience points, the amount of virtual money and current energy. The map is divided into tiles. Each tile represents a particular graphic image such as a tree, a house, a store, a fountain or grass. The student's goal is to click on every map tile and search for an item. Each search takes away energy points

from the user. If energy becomes too low, a student will not be able to continue searching quest. In this way, a user is prevented from playing the game for hours, and this feature may contribute to give player additional time until s/he gets bored.

The search on a specific spot may have the following results:

i. There is nothing on this location spot.
ii. There is piece of food.
iii. There is money.
iv. There is a hidden item.

If there is nothing found on a spot, a player continues searching in other tiles. If a search results in food retrieval, this may be consumed immediately or saved for later consumption. Saved foods are listed in the food section.

On the other hand, virtual money can be used to purchase new maps and, therefore, players may acquire new incentives to discover new places and hidden objects.

Finally, discovery of the existence of an item doesn't mean discovery of the item itself. At this point, the student has to deal with one of the available arithmetic games that is selected randomly by the main platform. The user can change the math game, but this substitution will affect his/her energy and reduce it by one point. This factor may prevent a player from selecting only desired games. If the student solves the math game, the hidden object will be unlocked and obtainable by the student.

Mini Game - Puzzle

As mentioned earlier, each time a student clicks on a particular spot on the map, the application displays a message informing the player about the existence of a hidden object. In order to pick up the object, the player has to solve a mini math game. There are a total of seven different math games so that player's interest can be raised and maintained at the highest possible rate. Each game has the same chance rate to appear and is linked to the subject of arithmetic in primary school.

In this paper, we don't describe all games but we present a puzzle game that differs from the classic puzzle games in that it incorporates educational features. On the left side of the game, there are several pieces with numbers on them. On the right side of the screen there is an empty book page that is divided into smaller numbered areas. Each piece on the left is the result of an arithmetic equation on the right. The student's goal is to drag the pieces from the left side on the corresponding spots on the right side and complete the picture by connecting all puzzle pieces. The puzzle game is illustrated in Figure 4.

Figure 4. The mini puzzle math game - multiplication case.

The game provides information on student's overall performance. Feedback includes the total number of answers submitted, as well as the number of submissions answered correctly and incorrectly. Each time the student drags a piece on the book, the game updates the statistics depending on answer correctness. An additional feedback is offered by playing a specific sound. In this way, when a student gets acquainted with game sounds, s/he can immediately understand if the answer imported is correct.

Finally, a significant feature of the game is the addition of a timer component. As soon as the puzzle game starts, the timer starts running. The timer is implemented in the form of a bar whose width gets smaller as time passes by. If the bar width becomes equal to zero, a student loses the game. However, each time a student submits a correct answer, the available time is increased.

Adaptivity

It is widely acknowledged that there are a variety of educational games or adaptive games. However, it is hard to find a game that combines both educational features and adaptivity. The mini puzzle game we mentioned earlier, takes advantage of a user-modelling component in order to filter students' answers and attach adaptive characteristics to the game. It is important to note that the rest of the mini games use the same component as well. The component's objective is to evaluate a student's knowledge level in each arithmetic operation and categorize him/her in the corresponding model. There are three models associated with the four arithmetic operations, beginner, intermediate and advanced.

When a student registers for a new account in the game, the application doesn't have information regarding his/her knowledge level. Hence, during the registration process, the game asks the student to fill his/her level for each operation. As a player participates in mini exercises during the game, the related knowledge level may be changed. The factor that defines the user model is the percentage of the correct answers. If the percentage is between 0 and 50%, the game puts the student in the beginner model. In cases where the percentage is between 50% and 80%, a student is categorized in the intermediate model. Finally, a total percentage above 80% results in putting a

player in the advanced level. It is important to repeat that the knowledge level may be different for each operation type. For example, a student may be associated with the advanced level in addition but may still be a beginner in case of subtraction.

Moreover, the game makes use of a database in order to keep a total history about each player's progress. Each time a student logs into the game, the system retrieves from the database the corresponding statistics and knows in which level categories the student is grouped.

Finally, the student-modelling component incorporates an error-diagnosis feature. Each time an incorrect answer is submitted, the model tries to determine the mistake type that user made. More specifically, in case of addition, it can be detected if a user has difficulties in solving equations with extras or adds all digits. Moreover, it can be checked if student implements a wrong operation type. If the incorrect answer can't be put in a specific error category, the model defines it as general addition error. Similarly, in the case of subtraction, the modelling component examines if an error is related to the subtraction of a greater number from a smaller one or is a general subtraction error. Correspondingly, an examination of error diagnosis takes place in cases of multiplication and division as well.

As mentioned earlier, the user-modelling component's objective is to filter students' answers and determine the corresponding knowledge level in each operation. Nevertheless, a student model is used to add adaptive characteristics in the game. Each time a student has to solve the mini puzzle game, the system selects one of the four arithmetic operations, depending on which operation the student has a low level. For example, if a player's knowledge level in multiplication is intermediate or advanced, but in addition is related to a beginner mode, the possibility of the system selecting addition is increased as shown in Figures 5 and 6.

id	name	password	level	hp	maxhp	exp	money	last_time	gender	level_add	level_subtract	level_multiply	level_divide
13	Georgia	1234567!!	1	92	100	144	3827	1365367029	2	1	1	2	2

Figure 5. Information about student named "Georgia." Addition and subtraction is 1 (beginner); in multiplication and division its 2 (intermediate).

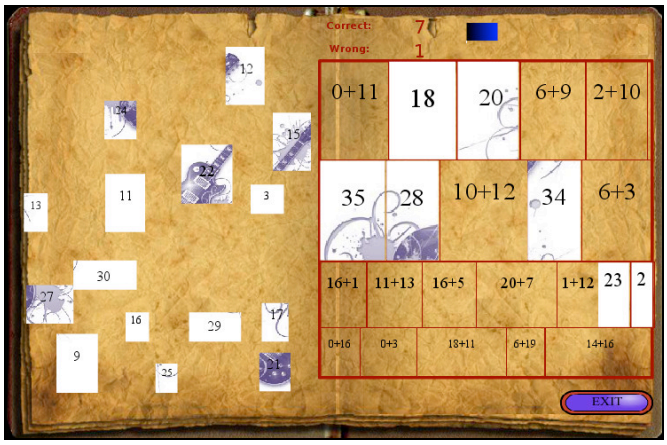

Figure 6. Math Puzzle Game selects addition operation type.

Moreover, if the selection is addition, the system examines the most common addition error types that are made by the students. For example, if a student has made mistakes in addition with extras several times, it is more likely to face similar problems in order to overcome difficulties related to this kind of exercise. The tutorials section updates the list that contains the suggested lessons and recommends each student to study particular tutorials (Figure 7).

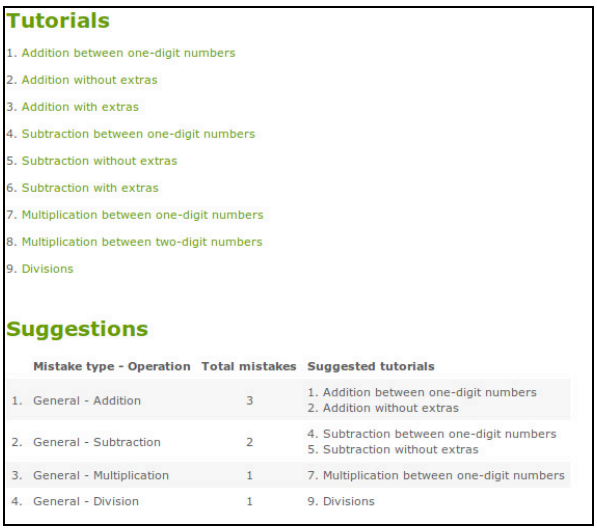

Figure 7. The top list contains tutorials. The bottom list contains recommendations about studying specific lessons depending on the error diagnosis.

Conclusions and Discussions

Browser-based games are simpler and more affordable for students. However, the field of browser-based games is still narrow and only few educational games belong to this category of games. Other studies note that games that incorporate adaptive features may contribute to help teachers assess students' performance while students may practice continuously in specific exercises in an enjoyable way.

In this paper, we have presented an educational game that combines the characteristics above and may be used as a motivational tool during learning process. The student's main objective is to obtain maps and search for items on several locations. To retrieve an item, it is necessary to solve an educational game in the context of arithmetic. Here, we described a variation of a puzzle game suitable for practising in arithmetic skills.

The game takes advantage of an implemented user-modelling process and an error-diagnosis, which makes it adaptive to the student's needs. It determines the student's weaknesses in arithmetic and provides him/her with corresponding game tutorials that may contribute to better understanding of specific arithmetic concepts.

One of our main future goals is to test whether the game is effective for improving students' skills in the context of arithmetic. Additionally, it is

important to determine students' perspectives concerning the use of adaptive games in educational process. One form of survey will take place in several classrooms in primary schools. An online study will also be conducted by integrating the game in social network sites taking advantage of the browser-based feature that the game incorporates. Lastly, we are working on developing more mini games on several educational subjects and attach them on the main game platform.

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