DESIGNING BOARD-GAMES FOR DEVELOPING PRE-SERVICE PRIMARY SCHOOL TEACHERS’ MENTAL CALCULATION SKILLS

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Abstract

Nowadays in the modern educational view the student should be an active participant of the learning process, and learning should be fun. Board-games have the potential to transform the learning from an activity seen as work to an activity seen as playing. Mental calculation skills are important not only for those working with numbers, but also in the everyday life. Developing mental calculation skills need a lot of practice, which can be boring. Board-games could help to make this practice fun. In this paper we focus on designing board-games for developing mental calculation skills. Three board-games designed by the author for pre-service preschool and primary school teachers for the Mathematics course they have in their second year of study are presented. But these games can be also used from primary school level to high-school level just changing the difficulty of the calculations involved. The games were tested and evaluated by the students participated in the course. Based on the evaluations some aspects related with designing mathematical games are discussed.

Keywords: board-games, mental computation, pre-service primary school teachers, mathematics education.

1 INTRODUCTION

Nowadays in the modern educational view the student should be an active participant of the learning process, and learning should be fun. Traditional games (card games or board games), or computer games transform the learning process from an activity viewed as work into an activity while having fun [20, 10, 5]. These games also make students responsible for their learning, as educational board games could increase students’ knowledge and develop their competencies even without a teacher to manage game activity [15]. Playing games could develop students’ critical thinking, problem solving competency, oral and written communication skills, and information analyzing abilities [1].

There are many educational games for different school levels. Here we give some examples of games used in higher education. O‘Halloran and Deale [17] designed a monopoly-like game for hospitality education. Taspinara, Schmidt, and Schuhbauer [23] developed a board-game for learning Knowledge Management (KM) models for students enrolled in the ‘Business Informatics’ BSc program. Leach, Foley, Olivas Osuna, and Molnar [11] designed a game for Economics courses, a game to illustrate the dynamics and limitations of markets. We also found an interesting idea, a board-game designed as a computer game. This digital board-game was created for learning concepts from law [7].

Board-games have potential for knowledge construction in Science Education [21, 6], and they can promote a positive attitude and motivation for learning Science [12].

Board-games are also suitable for developing different mathematical skills [22], as calculation skills, problem solving competence, strategic thinking. Mathematical understanding also can be developed through the discussions between students during the game [4].

In this paper we focus on designing board-games for developing mental calculation skills. Three board-games designed by the author for pre-service preschool and primary school teachers for the Mathematics course they have in their second year of study are presented. But these games can be also used from primary school level to high-school level just changing the difficulty of the calculations involved. The games were tested and evaluated by the students participated in the course. Based on the evaluations some aspects related with designing mathematical games are discussed.

2 DESIGNING BOARD-GAMES FOR EDUCATION

A game is “a rule-based system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player
feels attached to the outcome and the consequences of the activity are optional and negotiable” ([9], p. 36).

Designing educational games is important in order to have a variety of games from which to choose for developing different competencies or learning different contents. Game design “is the process of coordinating the evolution of the design of a game” ([3], p. 4).

Main elements of the game that contribute to learning are theme of the game, objectives, rules, adaptability to students’ competency level, and controllability.

The theme of the game set the context of the game [19, 2]. If the theme is interesting, the player is more involved in the game. The location of the game is also important and it influences the rules of the game [25]. The game’s goals give the conditions to win, thus they provide motivation for the player [8, 26].

The rules of the game can also contribute to the atmosphere related to the game’s theme. The rules set the way how the players progress on the board and establish criteria for how to win [2, 26]. Clear instructions on how to play the game is also important [18]. Players often learn to play a game from each other, by helping other players during the game or discussing about the game with them [24].

In order to address students with different knowledge and competency levels, the game’s rules should be formulated so that the player can choose the difficulty level during the game [13, 26]. Generally, students want to win a game using their skills, not only by luck [24]. Poor performing students appreciate an element of luck in the game, but, if the game is totally dependent on luck, it may become boring [18] or frustrating. The player should perceive a certain level of control over the game by making decisions in some moments during playing [16, 26]. Also, in order to keep students’ interest awake for the game, little variations are needed [18].

Among other factors that make educational games engaging for students we mention aesthetics and interaction between players. Aesthetics is the first contact with a game: having an attractive design, a game can become interesting even before knowing the rules. As regarding interactions between players, these could be cooperation or competition. Both interaction types could be a motivation factor for the players [14].

Another aspect when designing an educational game is the setup time and playing time. A game that takes too much time to set up or too long to finish is not suited for a one-hour class [18]. Also, a game that takes too much time to progress on the board could be boring.

3 PRESENTATION OF THE BOARD-GAMES DESIGNED FOR DEVELOPING MENTAL CALCULATION SKILL

We present the games designed for developing mental calculation skills. The games are mostly handmade for this pilot phase. After testing and making some modifications based on test result, the games will be professionally designed on the computer and printed.

3.1 Presentation of the game Zoo

In Fig. 1 the game Zoo is presented. This game contains cards from which the player build the "board". There are three type of cards:

- cards which have a piece of road on them, with a numerical calculation written on the road;
- cards which have an intersection of roads on them, with a number written to each road of the intersection;
- cards which have animals on them with a number written on each card.

The players have to calculate the result of the numerical calculation from the road, getting a number, and then join up with an intersection or an animal card having that number on it or join up two pieces of roads with the same result of the numerical calculations from them. The players get points for each card placed and the winner is that player who firstly achieve a certain number of points.

In this game there are a huge amount of variations for joining the cards, thus every game is different. The number of cards is quite high, so students won’t memorize the results in few games. The mental calculations involved are additions, subtractions, multiplications, two operation calculations:
multiplication with addition or subtraction, i.e. $8 \times 7 - 13$, $6 \times 6 + 11$, $90 - 5 \times 11$, $25 \times 3 - 60$. The multiplications are one digit number with one digit number or one digit number with two digit number.

3.2 Presentation of the game Amusement park

In the game the players walk around an amusement park and try as much rides as possible (see Fig. 2). The game has a board (left side of Fig. 2) on which the players walk around with a puppet, a ride collection board for each player, containing all the rides in greyscale pictures (right side of Fig. 2), cards with all the rides from the board (with color pictures), card with numbers between 1 and 10, and red and green coins (the red coin’s value is 2, the green coin’s value is 1). The board presents the amusement park with alleys and rides. The alleys contain circles with numbers on it. One can progress from a circle to another one, if he/she can choose two cards from what he/she has so that multiplying the numbers from those cards he/she gets the number from the circle where he/she wants to progress (i.e. if someone wants to progress to the circle with the number 8 he/she needs to have the cards 1 and 8 or the cards 2 and 4). In the colored circles the player gets red or green coins. Next to each ride the price for trying it is displayed. If the player arrives to a ride and has the correct amount of coins, he/she can collect a picture with that ride. The winner is who collect firstly all the rides. The mental calculations involved are products from the multiplication table.
3.3 Presentation of the game Magic castle

The game contains a board, cards with numerical calculations, and cards with different magical tools (see Fig. 3). The board present the paths to a castle, paths which goes thought a flowery meadow and a thick forest. In each turn the player pull a card, calculate the result, and progress that number of circles on the paths. In intersections the player can choose the direction in which he/she goes. In some circles some magic tools are hidden, as a key, a bone, a sword, and a magic wand; each tool can be found in more circles. The last 7 circles of the path representing the rainbow. There are other colored circles on the board, those one are shortcuts: a colored circle leads directly to the same colored circle of the rainbow. The player has to collect all four magic tools before arriving to the castle. The winner is who arrives firstly to the castle with all the tools collected. The game has a story: the player has to change the castle into life using the magic ward, after taming the wild dogs with the bone, opening the door with the key, and beating the dragon who leaves in the castle with the sword. The mental calculations involved are of two operation: a multiplication from the multiplication table and a subtracting, i.e. $31 - 7 \times 4$, $6 \times 6 - 33$, etc.
4 METHODOLOGY

4.1 Research goal
The aim of the research is to test the designed board-games with pre-service primary school teachers and refine the games based on the researcher’s observations during testing and the feedback obtained from the students.

4.2 Research participants
The participants in the research were second year Primary and Preschool Pedagogy specialization students of the Babes-Bolyai University: 33 students tested the game Magic castle, 27 students the game Zoo, and 17 students the game Amusement park.

4.3 Data collection
The board-games were tested during 2018/2019 university year at Mathematics course in the first semester and at Mathematics education course in the second semester.

Students got an evaluation sheet in case of each game with items measured on a 5-point Likert scale (for example, How much do you like the game?; How difficult the mental calculation were?; the scale was from 1 – not at all to 5 – fully yes) and 2 open questions (What did you like in this game? What would you change in this game?). In the case of the game Zoo only 2 closed questions where formulated, in the case of the other two games 7 closed questions where included in the evaluation sheet. The closed questions where quantitatively analyzed calculating mean and standard deviation for each item. The open questions were qualitatively analyzed extracting the reasons they liked each games and also the ideas which could improve the games.

The researcher observed each group of students how they play and noted the problems she observed.
5 RESULTS

5.1 Students’ answers to the closed items of the games’ evaluation sheet

In Table 1 the means and standard deviations in the case of the closed questions are presented. These questions were measured on a 5 point Likert-like scale, where 1 means not at all and 5 means fully yes. Based on the results we could observed that students enjoyed all three games, as the mean of the related question is high (between 4.61 and 4.76) and the standard deviations are not high (between 0.42 and 0.60). The highest mean is for the game Amusement park, the second highest is for the game Zoo, and on the third place is the game Magic castle. But the difference between averages is very small. Students also agree that the games Amusement park and Magic castle significantly contributes to the development of the mental calculation skills (M=4.82 and SD=0.38 respectively M=4.91 and SD=0.29). The difficulty of the mental calculations involved was considered medium by the students (M=3.30 and SD=1.18, M=2.71 and SD=1.07, respectively M=2.67 and SD=1.15). It is interesting, that the difficulty of the calculations in case of the Amusement park game is not significantly lower, than in the case of the other two games, even if this game involves only products from the multiplication table. Students felt that they have a choice when playing in case of both Amusement park (M=4.59 and SD=0.60) and Magic castle (M=4.24 and 0.74) games. Respondents consider the speed of the games Amusement park (M=3.71 and SD=0.91) and Magic castle (M=3.82 and 0.83) above average.

<table>
<thead>
<tr>
<th>Zoo</th>
<th>Amusement park</th>
<th>Magic castle</th>
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<tbody>
<tr>
<td>M</td>
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<td>St. Dev.</td>
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<td>St. Dev.</td>
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<td>M</td>
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<tr>
<td>St. Dev.</td>
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<tr>
<td>How much do you liked the game?</td>
<td>4.70</td>
<td>0.60</td>
</tr>
<tr>
<td>How difficult the mental calculations were?</td>
<td>3.30</td>
<td>1.18</td>
</tr>
<tr>
<td>How much the game contributes to the development of mental calculation skills?</td>
<td>4.82</td>
<td>0.38</td>
</tr>
<tr>
<td>How much you checked if the other players have calculated correctly the answers?</td>
<td>2.94</td>
<td>1.16</td>
</tr>
<tr>
<td>How spinning the game was?</td>
<td>3.71</td>
<td>0.91</td>
</tr>
<tr>
<td>How much did you feel you have a choice?</td>
<td>4.59</td>
<td>0.60</td>
</tr>
<tr>
<td>How much the game’s outcome depends on luck?</td>
<td>3.47</td>
<td>0.70</td>
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5.2 Students’ opinions and recommendation of changes in case of the game Zoo

The students really enjoyed constructing the net of roads, the mental calculation was just a tool for this aim. One of the students said:

I really liked it, I enjoyed it so much, that when the teacher said we should stop, I continued to play alone pulling new card and continuing to construct more roads.

This game didn’t have a specific goal, the players just collected points, and the winner is who achieved a certain number of points. But the game can be stopped in any moment and consider the winner the player who has the most points at that moment.

In the rules to each type of card was assigned a certain number of points: 1 point for a card with a piece of a road, 1 point to an intersection which closes a road from 1 or 2 pieces, 2 points to an intersection which closes a road from at least 3 pieces, 3 points for an animal card. Students considered unfair to get 3 points for an animal card, for which they don’t need to make any mental calculation. The researcher consider that the point collection rules should be revised.
Based on the students’ opinion and the researcher’s observations during testing of the game, she consider that a proper aim for the game would be more motivating than only collecting points. An idea would be to make a board with a grid containing squares of the size of the cards. At the beginning of the game the animal cards are set randomly on this board. The aim of the game would be to connect the animal cards with roads. In this way the game would be a collaborative game, not a competitive one. But this change is significant, it needs to write new rules, to revise the cards, and then test this mainly new game again.

5.3 Students’ opinions and recommendation of changes in case of the game Amusement park

The students liked the theme of the game and considered it interesting, because beside the mental computation they have to be aware of more aspects, as collecting money, choosing the way to the rides, etc. They also liked that they could plan more steps in advance based on the cards from their hands.

Based on the researcher observation and the students’ feedback, it takes quite a long time to finish the game. Especially in the beginning it is hard to progress because the players don’t have the right cards for it. To solve this problem there were some recommendations, as drawing more connections between circles, having more cards, and giving the possibility to switch cards between players. We tried the game introducing in the rules the possibility of switching cards between players, and the game was more spinning. Another idea for getting the right cards is to have a so called bank with some cards in it, and the players can switch a card with a card from the bank.

To reduce the time necessary for completing the game, the number of the white circles from the board should be reduced, and maybe the number of the coloured circles should be increased. Eliminating white circles the player could progress quicker to the rides, introducing more coloured circles the player could collect quicker the money necessary for paying the rides.

5.4 Students’ opinions and recommendation of changes in case of the game Magic castle

Students enjoyed the story of the game and the fact that the game has a final goal. They liked that it is possible to choose the path which one to go, even it is allowed to turn back from an intersection. They also valued the idea of the shortcuts using the coloured circles.

The story and the design of the game determine the players to make mental calculations willingly.

I was motivated to calculate the results of the operations as I was curious to find the number of steps I should go in order to see if I get or not a magic tool.

Students suggested to have more circles with tools in order to collect all of them in shorter time. The rules of the game required to pull the exact number of steps for entering the castle, and this held in place those players who already collected all the tools and entered the rainbow path. Students considered this rule not adequate for the game. Maybe this rule contributed to the fact that many students considered that this game’s outcome depends quite a lot on luck (Table 1: M=4.06 and SD=0.78). Both suggestion are good and the researcher consider to use them when revising the game.

There were suggestions regarding the operations from the cards, as using smaller numbers or including operations with bigger results to be able to progress more on the board. Another suggestion is to write the result of the operations on the back of the cards. The researcher didn’t give the results because she considered that all the players should calculate each operation in order to check the correctness of the solution. But taking in consideration that the average for checking the solutions of the other players was not so high (Table 1: M=3.12, SD=1.27), maybe giving the results would speed up the game.

We also tried to play this game in pairs. In this version of the game two players collected together the magic tools, but they had separate puppets on the board. This speeded up the game. We tried both the individual and the pair version with 10 students, 4 of them enjoyed more playing individually, 6 of them liked more playing in pair.
6 CONCLUSIONS

As regarding the three games presented in this paper, the following conclusions could be done:

- All the games are enjoyable by the students, they liked the theme of them, and they liked playing them.
- All the games significantly contributes to the development of the mental calculation skills. Two games, Zoo and Magic castle requires quite difficult mental calculations. It is tiredly to make many higher difficulty calculation in row. Maybe some easier calculations should be also included. Also, in case of the Zoo and Magic castle games set of cards with different difficulty level should be developed, thus the games could be more adaptable to the competency level of the players.
- All the games are quite long, they would take most of a lesson if introducing them in primary school. In this way all the games should be revised in order to reduce the necessary time for completion. In the result section some ideas are given for this purpose in case of each game.

As general conclusions regarding educational board-games for developing mental calculation skills, we found that:

- The theme and the final goal of the game is important for motivating students in doing the mental calculations. If students found the story of the game interesting they “forget” that they do maths, they only try to fulfil the goal of the game.
- If the player feels that she/he has a choice and the outcome of the game doesn’t entirely depend on luck, he/she is more motivated to play. For this purpose a net of paths should be used instead of a single path in case of boards with a path to follow to get from the start point to an end point or to reach different parts of the board. In case of a net the crawl order is not fixed, in the intersections the player could decide the direction to take.

ACKNOWLEDGEMENTS

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REFERENCES