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SERIOUS FUN WITH MATHS: GAMES THAT ENGAGE AND TEACH

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Abstract

Play is a natural way to develop thinking and is part of children's daily lives in their early years. In this sense, the adoption of gamification strategies by pre- and primary school teachers has become increasingly common. Several studies highlight the positive impact of adopting this teaching/learning strategy. Recognizing the advantages of using games as a pedagogical strategy and understanding that children have a high predisposition to develop mathematical skills in their early years, the first author of this article organized a workshop intended for both pre-service and in-service pre- and primary school teachers. The workshop aimed to explore the use of non-digital games as educational tools for teaching and learning mathematics. Considering various research indicating that one of the reasons for gaps in mathematical knowledge is the lack of connection between formal learning and the child's informal and intuitive knowledge, which is especially harmful when informal knowledge is poorly developed, the games explored were designed to be used both in the classroom and at home with the family. Participants had the opportunity to experience a variety of games designed to make the teaching of mathematics more engaging, interactive, and enjoyable for children. The benefits of using games as a pedagogical strategy were also discussed. To assess how workshop participants perceived the use of gamification in the mathematics teaching-learning process, a survey was conducted. Our findings suggest that the participants recognized the potential of using games in the mathematics teaching-learning process and intend to incorporate this resource in their pedagogical practices.

Keywords: *Educational games, game-based learning, non-digital games, gamification, mathematics education.*

1. Introduction

Exploring through play, an intrinsic aspect of children's daily routines, comes naturally and contributes to the cognitive development of children (NCTM, 2008). Children develop mathematical thinking and reasoning in various contexts, especially when they have sufficient knowledge about the materials they are using (such as toys and games), when the activity is motivating and arouses their curiosity, and when the context is familiar to them (Alexander, White & Daugherty, 1997). Hence, children's everyday experiences while playing and exploring are extremely powerful. According to Baroody, Clements & Sarama (2019) "there is no reason why early mathematics instruction must be joyless or crowd out non-academic instruction" (p. 330). In this sense, the adoption of gamification strategies by pre- and primary school teachers has become increasingly common. Several studies (Kapp, 2012; Baroody et al., 2019; Dinata, 2021) highlight the positive impact of adopting this teaching/learning strategy. "Games can provide an engaging opportunity to practice and extend skills. If children have fun playing the games, they are more likely to be motivated to practice math. For maximum benefit, teachers should select specific games to match current math objectives" (Frye et al., 2013, p. 54). Structured play in the form of well-chosen games can provide high quality educative experiences (Baroody et al., 2019).

One of the many reasons given by several authors (Frye et al, 2013; Bassok, Latham & Rorem, 2016; Baroody et al., 2019) for involving young children in mathematics instruction is that early informal (everyday and largely verbal and manipulative) knowledge of mathematics provides an important basis for learning school (and largely written) mathematics and other academic content. Authors such as Frye et al. (2013) and English (2016) argue that it is the responsibility of educators/teachers to promote

enriching mathematical experiences for their students. They can and should plan and design both formal and informal experiences with intentional purpose, creating learning opportunities that align with the interests and needs of the children. Thus, early childhood teachers must "dedicate time that targets mathematics each day and look for opportunities to integrate mathematics throughout the school day and across the curriculum" (Baroody et al, 2019, p. 330).

Recognizing the advantages of using games as a pedagogical strategy and understanding that children have a high predisposition to develop mathematical skills in their early years (Perry and Dockett, 2002; Clement, Sarama & DiBiase, 2004; Baroodi, Lai & Mix, 2006; Bassok et al., 2016), the first author of this paper organized a workshop intended for both pre-service and in-service pre- and primary school teachers. The workshop aimed to explore the use of non-digital games as educational tools for teaching and learning mathematics.

The authors have intentionally opted for non-digital rather than digital games since the former do not require technological resources which many schools and children do not possess. The games proposed only require accessible materials such as paper and dice. Additionally, they also wanted to avoid contributing to the increase in time that young children already spend on screens.

Taking into account multiple research findings that highlight the lack of connection between formal learning and a child's informal and intuitive mathematical knowledge as a contributing factor to knowledge gaps, particularly when the informal knowledge is underdeveloped (Hiebert, 1986; Griffin, Case & Siegler, 1994; Frye et al., 2013), the games explored were created to be used both in the classroom and at home with the family.

2. Methodology

The aim of this study is to understand how both pre-service and in-service pre- and primary school teachers perceive the use of non-digital games as educational tools for teaching and learning mathematics to young children.

In this case study, inquiry techniques and direct observation were used, employing the following instruments: field notes and questionnaire. During the workshop, the teacher (first author of this article) adopted the participant observation technique. The questionnaire aimed to gather information about both pre-service and in-service pre- and primary school teachers' perceptions concerning the use of gamification in the mathematics teaching-learning process. After data collection, qualitative analyses were carried out, quantified whenever necessary and possible. Statistical analysis was performed using Excel.

2.1. Respondents

The respondents of this case study were 12 participants of the workshop. This was a convenience sample, as participants were easily accessible to researchers.

With reference to the profile of the respondents, ten participants (83.3%) were in-service school teachers, and only two (10%) were students - pre-service pre- and primary school teachers. Among the in-service teachers, six (60%) were pre-school teachers, three (30%) were primary school teachers and one (10%) didn't teach mathematics. Most respondents were female (91.7%), whereas only one (8.3%) was male. Regarding their teaching experience, among respondents who are already teaching, eight (80%) had more than 20 years of service, one (10%) between 11 and 20 years of service and another (10%) between 5 and 10 years of service.

2.2. Description of the workshop

The workshop, entitled "Fun Family Mathematics: Games that Captivate and Teach" occurred within the VII CICA (International Interdisciplinary Congress on Children and Adolescents) that took place at the University of Azores, in October 2023. It was a two-hour workshop and had 14 participants.

The goals of the workshop were to explore the use of non-digital games as educational tools for teaching and learning mathematics, in formal or informal contexts (with family); show that it is possible to reconcile the benefits of the game environment with the learning process, whether in the classroom or in the family environment; introduce some concrete games that can be adapted by participants to their specific contexts.

The workshop started with a discussion about the benefits of playing games in childhood and the use of educational games in the classroom. Afterwards the participants had the opportunity to experience three games chosen due to their varied game rules and high potential to be adapted to different mathematics contents. In the end the participants answered an opinion survey.

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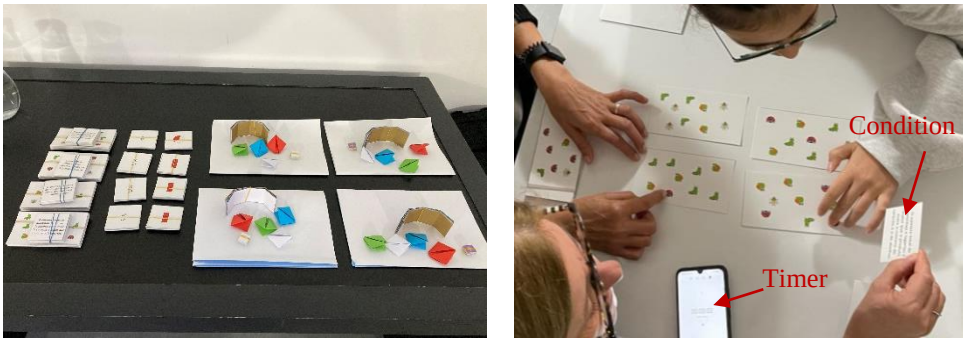
3. Results

3.1. The games played

In this section we briefly describe the games played at the workshop. They were created by the authors of this paper and one of them was specifically adapted to the Azorean context. The last two authors of this paper have a long experience in mathematical games design for formal and informal contexts, and have dynamized several workshops in conferences and professional development courses for mathematics teachers in the last years (La Fortuna, Morando & Spreafico, 2022; Morando & Spreafico, 2023; Morando & Turconi, 2022). The games are easy to reproduce and only require accessible material such as paper, dice, and timers. Figure 1 (left) shows the materials used for the three games, four copies of each.

In the first game, Garden Animals, there are two decks of cards: one with images of sets of garden animals (combining bees, snails, ladybirds, and caterpillars) and the other with numeric conditions (for instance: there are more snails and bees together than there are caterpillars). In turns, each team takes a card from the conditions deck and has a limited time to identify from a set of four image cards those that satisfy the condition. Those image cards are collected by the team and replaced by new image cards. When the game finishes (no more image cards available) the team who collected more image cards wins. Figure 1 (right) shows two teams playing the game, using the mobile phone as a timer.

Figure 1. Game materials (left) and participants playing Garden animals (right).



In the second game, Math Twins, there is a deck of pairs of cards, each pair consisting of a fraction and a corresponding diagram (see example in Figure 1, left). The total number of cards must be an even multiple of the number of players. The cards are shuffled, and the deck is evenly distributed by all players. The game starts by allowing players to look for pairs in their cards and put them aside. Afterwards, all at the same time, players randomly remove one card from their left-hand neighbour and check if a new pair can be formed. This step is repeated until one player runs out of cards. At this point the game ends and this player is the winer. Figure 2 (left) shows four players playing the game and two matching pairs of cards.

In the third game, Arithmetic Tour of the Azores, there is a board with the nine Azorean islands, each one with a tower of selected numbers and points to be collected by the teams. Each team has a boat to travel between islands. In turns, each team draws a pair of dice, numbered 1 to 10, and to travel to an island the team must obtain one of the numbers of the island tower by adding, subtracting, multiplying or dividing the dice results. If an island is occupied by a team, no other team can dock there. The first team to collect one point from each island wins the game. Figure 2 (right) shows the game being played using digital dice available at https://polypad.amplify.com/p#polyhedral-dice.

Figure 2. Participants playing Math twins (left) and Arithmetic Tour of the Azores (right).

3.2. Analysis of questionnaires

The first section of the questionnaire concerned the characterization of the respondents, summarized in Section 2.1. The main section of the questionnaire had 5 questions. In the first question, participants were asked to rate, through a five-point Likert scale (1-very negative; 5-very positive), their general evaluation of the workshop (first line of the heatmap in Figure 3). In the next two questions, they were asked to rate their agreement, on a five-point Likert scale (1-total disagreement; 5-total agreement), over two sets of statements about the workshop. As can be seen from the heatmap of responses and corresponding statistics of these three questions (**Error! Reference source not found.**), the course was well evaluated and the general opinion about the use of gamification in mathematics classes was positive.

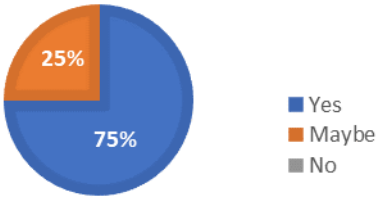
Although all the global evaluations of the workshop were positive, there were four negative opinions (level 2 of agreement) and several neutral opinions (level 3 of agreement) in the remaining questions. The questionnaire was made using Google forms and we have noticed later that keeping the mobile phone in vertical position, for questions 2 and 3, only the first 2 or 3 choices of the Likert scale are visible, and the user has to scroll the bar to the right to see the remaining options. It is possible that some participants did not realize this and that would explain the apparent contradiction between answers.

Figure 3. Heatmap of responses with corresponding mean and standard deviations.

	1	2	3	4	5	Mean	Std.Dev.
Overall, how do you rate this workshop?	0	0	0	4	8	4,7	0,5
The topic was relevant.	0	1	2	0	9	4,4	1,1
The workshop met my expectations.	0	1	2	0	9	4,4	1,1
The activities were interesting.	0	1	2	0	8	4,4	1,1
I think that using gamification in mathematics classes:							
is important.	0	1	2	4	5	4,1	1
provides a more interesting learning method.	0	0	3	4	5	4,2	0,8
makes learning more interactive.	0	0	3	2	7	4,3	0,9
makes the classes more stimulating.	0	0	3	2	7	4,3	0,9
contributes to a more positive view of mathematics.	0	0	4	2	6	4,2	0,9
involves the students in the learning process.	0	0	4	3	5	4,1	0,9
increases students' motivation.	0	0	4	2	6	4,2	0,9
contributes to achieving better results.	0	0	4	2	6	4,2	0,9

Participants were asked if, after this workshop, they intended to use gamification in their classes. Figure 4 shows that most participants intend to use gamification and there were no negative responses.

Figure 4. Pie chart of responses to the question "Do you intend to use gamification in your classes?"



Finally, the participants were asked to write further comments on the workshop. Three respondents provided comments which we transcribe next:

Excellent!

I found it very interesting and relevant since today's students are so-called "digital natives".

Very practical and functional. I have to make some adaptations for preschool. Thanks!

This last very positive comment was given by a pre-school teacher who had a neutral opinion in all statements, except for the overall evaluation of the workshop which was "Very good". As mentioned previously, this contradiction is likely to be the result of wrong choices due to the mobile phone layout.

Direct observation during the workshop revealed that participants were enthusiastically involved in the games, and many expressed their intention to use the games (or adaptations) with their students.

4. Conclusions

In this work we analyze the use of mathematical educational games for pre- and primary school children by showing three games that can be used both in school context and at home with the family. The selected games are easily adaptable to other topics and thus constitute new materials for teachers to

use in their practice. The results of this study are clearly positive, with teachers expressing enthusiasm for this type of experience, recognizing the potential of using games in the teaching-learning process, and showing interest in incorporating this resource into their pedagogical practices.

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