THE CREATION AND VALIDATION OF A DIGITAL PEDAGOGICAL GAME FOR THE TEACHING OF PROBABILITY IN THE EARLY YEARS OF ELEMENTARY SCHOOL

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We consider teaching probabilistic concepts using an educational digital game. In particular, we seek to validate the game's usefulness through the evaluation of basic education teachers who teach this probabilistic content in their classrooms. We believe that, in addition to creating, developing, and organizing resources and materials for teaching, it is essential that the materials are evaluated to validate their effectiveness for teaching and learning. We seek to offer teachers and students greater possibilities for didactic work by offering digital educational activities for student learning.

INTRODUCTION

With this research, we seek to reinforce that probability can be taught to students at an early age. We also seek to present an educational digital game that can make the teaching and learning of probability playful for both teachers and their students. We believe that play is part of every child's formation. Digital games can contribute to student learning because they can present educational challenges to students and be shared among children during classes while providing entertainment and fun that can be motivating for children. Additionally, when we provide educational digital games as an alternative to traditional probability instruction, we expand students' probabilistic skills and competencies while tapping into the creative potential of our students.

According to the National Common Curricular Base–BNCC (Ministério da Educação [MEC], 2018) in Brazil, learning in mathematics is intrinsically related to understanding. Important for students' development of mathematical (and probabilistic) understandings are the connections that students make among concepts and procedures and with their daily lives. Teaching resources such as square grids, games, books, videos, calculators, spreadsheets, etc., can play an essential role in developing understanding and using probabilistic concepts, and these materials need to be integrated into situations that lead to reflection and systematization so that students move from the concrete to abstract formalizations of probability (MEC, 2018). In everyday life, students make oral reports and reflect on the past songs and games taught by their elders. Through reflection on developing understandings applied to everyday life, they begin to raise hypotheses and develop understandings about different situations.

In previous studies (Oliveira Júnior & Datori Barbosa, 2020; Oliveira Júnior, Ciabotti et al., 2019; Oliveira Júnior, da Silva, et al., 2017; Oliveira Júnior, Datori Barbosa, et al., 2019; Oliveria Júnior, Fernandes, et al., 2015; Oliveira Júnior, Machodo, et al. 2013), teachers used a manipulable version of a game to teach probability. We base our study on the teaching of probability using a digital version of the game. The game was created with the aim of being used in the classroom as a tool for teaching probability in the early years of elementary school. The original game is a board game with two types of cards that present students with problems to solve: (a) questions cards in which students are presented with everyday problem situations that can be solved using probability and (b) learn more cards (+) that present different types of probabilistic information and require different areas of knowledge to solve. The entire process of building the game tasks was supported by BNCC (MEC, 2018), which includes probabilistic content and skills for students in their initial years (1st to 5th year) of elementary school. The tasks also are supported by the Anthropological Theory of Didactics–TAD (Chevallard, 1999), which allowed a praxeological, mathematical (probabilistic), and didactic analysis of the tasks proposed in the game cards to expand teachers' views of the objects of knowledge for this stage of their teaching.

We conducted a systematic review of the literature to find works that offered important elements for understanding the importance and contribution of physical and digital games to the teaching and learning of probability. The results converged on the ideas of Grando (2000), who stated that a game can allow teachers to understand a student's thinking and to adjust instruction based on that understanding, and the ideas of Fonseca (2005), who suggests that a game offers many

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possibilities for teaching that are integral to a child's development. The review also revealed a need for more studies in this area of research and the creation of new pedagogical resources, more specifically, digital games. Given the current COVID-19 pandemic and recent technological advancements, a gap was found in relation to the creation, development, and use of digital games for teaching probability in the early years. Of the 15 works we found that focused on physical and digital games in the teaching and learning of probability, only three used games with this technological format. This gap in literature is concerning because, according to Reis (2017), emerging technologies increasingly tend to attract the attention of students, and in this context, digital games can provoke greater interest and involvement in activities, which reinforces the need to create, develop, and use digital games in the classroom. However, we emphasize that creating and developing games or using games in the classroom does not guarantee student learning. Moura (1992) points out that teachers need to be intentional and focused on promoting learning when choosing a game as a teaching strategy.

In addition to creating and/or adapting didactic resources, resources need to be validated. The tasks proposed for the educational digital game focus on the concepts of probability, and we use the game as a teaching tool to work with children. We seek validation of the game as we answer our research question: Can the digital version of the game be considered a methodological tool for teaching probability in the early years?

METHOD

We initially consider Amstel (2005), who defines usability as a synonym for ease of use. If a product is easy to use, the user is more productive and can learn faster, memorize operations, and make fewer mistakes. In addition, according to Nielsen (2012), usability is a quality attribute for evaluating the ease of use for a given interface in the area of Human-Computer Interaction (HCI). We also highlight the work of Nielsen (1994), who lists five quality components for usability: (a) ease of learning, which refers to the ease with which users can perform basic tasks the first time they use a system; (b) efficiency in use, which refers to how quickly users can perform tasks after they learn to use the system; (c) ease of memorization, which refers to how easily users can complete activities after a period of time without using the system; (d) error prevention, which refers to the number of errors that can occur while users use the system, how serious they are, and how easily they can recover from these errors; and (e) user satisfaction, which is the satisfaction the user feels when using the system.

To evaluate the usefulness of the digital game, we asked teachers who teach mathematics in basic education and who work in the early years of elementary school to complete a questionnaire. These 19 teachers were enrolled in an extension course that included a component titled "Teacher training based on a pedagogical game for teaching probability in the early years of elementary school." The course was offered by the Group of Studies in Statistics and Mathematics Education–GEEM at the Federal University of ABC–UFABC, and the portion of the course used for this study was designed to present the game to teachers and for teachers to explore the game. Teachers' access to the digital game occurred through the researchers' presentation of a prototype in a class in the ninth week of the course. The presentation focused on the mechanics, rules, and logic of the game. At this stage of the prototype, there was no scenario. We presented a "test" mini game, which was a very simple roulette wheel and some graphic art elements such as stylized game houses and the Pathfind (route tracker) moving character.

Teachers were asked to complete a questionnaire through Google Forms to evaluate the applicability of the game at the end of their extension course. The questionnaire was designed to provide valuable information about the design and usability of the game and the game's feasibility for use in the classroom as well as a critical analysis of the game. The questionnaire was divided into sections, with the first section dealing with sociodemographic aspects to profile the teachers participating in the evaluation. In the remining sections of the questionnaire, teachers indicated the degree of their satisfaction for aspects related to the usefulness of the game. Teachers recorded their responses to seven items (displayed in Table 1) using a five-point Likert scale (1 to 5): (1) I totally disagree; (2) I partially disagree; (3) I neither disagree nor agree; (4) I partially agree; (5) I totally agree. For Petri, Von Wangenheim, and Borgatto (2019), usability is fragmented into four sub-

dimensions: aesthetics, learnability, operability, and accessibility. These dimensions were measured in this study by using the MEEGA+ model for evaluating digital games used in teaching.

We used Factor Analysis (FA) to analyze the data. According to Hair et al. (2010), FA is an interdependence method in which all variables are considered simultaneously. Each variable is predicted by all others. Thus, dependency techniques aim at prediction and explanation, and interdependence techniques aim at identifying structure. In addition, for Matos and Rodrigues (2019), factorial techniques can achieve goals from an exploratory perspective (Exploratory Factor Analysis–EFA) or from a confirmatory perspective (Confirmatory Factor Analysis–CFA). In this study, we used EFA to let the observed data determine the underlying factorial model a posteriori, inductive reasoning to infer a model from the observed data (Bryant & Yarnold, 1995). Thus, the EFA was aimed at discovering which factors, i.e., latent variables or constructs, underlie the variables under analysis (Urbina, 2007). As supported by Matos and Rodrigues (2019), EFA is generally used in the most embryonic phases of research to explore data, and in particular the relationships among a set of variables to identify patterns of correlation. Thus, we used the EFA to define the factors that explain its covariance.

RESULTS

Initially, we observed that research participants' average attributions for the seven items displayed in Table 1 are greater than 4.1. Because a response of 5 on the Likert score indicated total agreement with statements, high scores for each item indicate a positive evaluation for that element of the game. Thus, there is an indication that, in general, teachers positively evaluated the game in terms of its usefulness.

Table 1. Result of Exploratory Factor Analysis in the scale generating items

Scale Item	Description	Scale Factors	
		Aspects regarding the aesthetics and operability of the game (Structure)	Aspects related to game learning (Learning)
1	Game elements are attractive (character movement, die designer, houses, and cards)	0.889	
5	The game rules are clear and understandable.	0.736	
6	The fonts (size and style) used in the game are readable.	0.941	
7	The colors used in the game are understandable.	0.945	
2	There are few things you need to learn to start playing the game.		0.808
3	I consider the game to be easy to play.		0.768
4	I think most people would learn to play this game quickly.		0.871

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization
Rotation converged in three iterations

We then applied EFA to verify the dimensionality of the scale. A verification of KMO = 0.699 and Bartlett's Test of Sphericity = 136.761 ($p < 0.001$) suggested that factor analysis was appropriate, because in the case of the sphericity test the p value tends to zero and the Kaiser-Meyer-Olkin (KMO) test value is greater than 0.5. EFA was applied to the seven items of the scale. Based on the results indicated by the rotating component matrix, EFA resulted in two components or two factors relating to the usability analysis of the digital game prototype for this study. Because factor loadings for the two factors are greater than 0.6, and with 19 participating teachers, the sample of this study is sufficient to generate the analyses and consider the results to be significant (Field et al.,

2012). The two factors together explained 85.677% of the total variation attributed to the scale items, with the first factor accounting for 70.936%. Taking the indications of Petri, Von Wangenheim, and Borgatto (2019) into consideration, the first factor includes aspects related to the digital game interface, allowing a pleasant and satisfactory interaction with the user and having attributes that facilitate operation and control. The second factor indicates aspects related to users learning to play the game easily and quickly.

In addition to these aspects, it is important to consider the application of any data collection instrument for reliably producing respondents' thoughts about the tool. According to Nunnally (1978), a Cronbach's alpha value of at least 0.70 would be an acceptable reliability value. In this study, the degree of reliability (Cronbach's alpha) of responses was 0.913, which confirms the high internal consistency of the scale. The data included in Table 2 show Cronbach's alpha values for the factors generated from the EFA. Because the reliability coefficients are greater than 0.7, they confirm the instrument's internal consistency (Pasquali, 2003). The scale can be considered two-dimensional (digital game structure and learning to play quickly and easily) and measures aspects related to the game's usability.

Table 2. Cronbach's reliability coefficient of the factors generated in the AFE

Factors	Cronbach's alpha	Number of items
Aspects regarding the aesthetics, accessibility and operability of the game (Structure)	0.944	4
Aspects related to game learning (Learning)	0.845	3

DISCUSSION

MEGAA+ is used to assess the quality of educational games used for teaching computer science and software engineering, considering the player's experience and perceived learning from the players' point of view. The MEGAA+ instrument includes a kit composed of analysis worksheets and a questionnaire that can be used by teachers, game creators, and people who work on game research in order to evaluate the quality of educational games in a practical way for both digital and non-digital games.

In the case of this study, we evaluated usability, which is one of the characteristics that applies to educational software or games when they are easy to navigate, as well as information that helps the player to work with the game's interface. This study sought to rely on the ISO/IEC 9126 standard (Gladcheff et al., 2011), in which the quality of a software or a digital game is defined as the characteristics of a product that gives it the ability to satisfy explicit and implicit needs.

The results of this study suggest that the game is a quality digital game according to the group of practicing teachers who participated in this research and by converging to what Cipriani (2007) indicates. The game does not present implementation errors, properly follows the international recommendations on software usability, and is versatile enough to allow the content to be adapted to the needs of the educator.

We sought to evaluate the prototype of a digital game aimed at teaching probability for the initial years of elementary school in Brazil, particularly seeking information for its improvement and about its qualities and usability for teaching. This study indicates that the digital game prototype has characteristics that meet the perceived needs of classroom educators according to the usability indications proposed by Petri, Von Wangenheim, and Borgatto (2019). The game allows for a pleasant and satisfying interaction with users and has attributes that facilitate operation and control, as well as those related to users learning to play it easily and quickly.

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