INSTRUMENTAL GENESIS OF THE DIGITAL EDUCATIONAL RESOURCE (DER) "FUNÇÃO RESGATE"

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Abstract: This paper analyses two phases of the instrumental genesis process of 36 in-service mathematics teachers, which consist of learning about and evaluating the digital game Função Resgate, designed to teach algebraic and transcendental functions in secondary school. Two questionnaires with a three-level Likert scale were applied and four semi-structured interviews were conducted with teachers intentionally selected from among the respondents. The opinions of the teachers are analysed and how they would affect the use of digital games in their classes.

Key – words: Digital Game. Mathematics teachers. Algebraic and transcendent functions

Résumé : Cet article analyse deux phases du processus de genèse instrumentale de 36 enseignants de mathématiques en exercice, qui consistent à apprendre et à évaluer le jeu numérique Função Resgate, conçu pour enseigner les fonctions algébriques et transcendantales au secondaire. Deux questionnaires avec une échelle de type Likert à trois niveaux ont été appliqués et quatre entretiens semi-structurés ont été menés avec des enseignants intentionnellement sélectionnés parmi les répondants. Les opinions des enseignants sont analysées ainsi que la manière dont elles affecteraient l'utilisation des jeux numériques dans leurs classes.

Mots clés : Jeu numérique. Professeurs de mathématiques. Fonctions algébriques et transcendantes

Introduction

Digital game-based teaching has demonstrated its effectiveness in numerous studies (Liu et al., 2021), highlighting its role as a generator of stimulating and enjoyable experiences for students. It sustains attention for long periods, fosters curiosity, and cultivates a taste for challenges and the efforts they entail—factors that effectively drive the learning process. Despite the high potential offered by the combination of teaching and digital games, their integration into the educational environment requires adoption by teachers.

In this work, we evaluate a group of in-service mathematics teachers on a game created to teach mathematical functions in secondary school (Gomes et al., 2022), with the aim of using it in their classes. It is noted that, although games and the use of mobile devices are familiar to students, they are not as familiar to teachers and their use in the classroom. Consequently, it is relevant to investigate the instrumental genesis of digital resources carried out by mathematics teachers in training and in service.

Theoretical framework

The Instrumental Approach of Didactics (IAD) (Rabardel, 1995) was developed in the field of Professional Didactics (Pastré, Mayen, and Vergnaud, 2006) to analyze and understand how a person using an artifact in a work situation builds a scheme of use for that device (Vergnaud, 2013). In this context, a process of appropriation occurs, which requires distinguishing between the artifact itself and the instrument that appropriation generates. Through this process, known as instrumental genesis (Rabardel, 1995), the artifact becomes an instrument for the user. For teachers, their activity with the artifact and the situation that promotes its use are determining factors. Throughout their professional lives, teachers undergo various instances of instrumental genesis, generating knowledge that allows them to decide and act quickly, adapt to changes in tasks, and ensure productive and viable results (Otero & Gazzola, 2022).

Instrumental genesis (IG) comprises two interrelated processes (Rabardel, 1995): instrumentalization, which refers to how the subject assimilates and personalizes the use of the artifact in a given training or work situation based on their existing schemes, and instrumentation, which occurs when the subject restructures their action based on the artifact to perform the task, modifying their schemes. These processes are dialectical and ongoing; regardless of a professional's expertise with an instrument, there will always be potential to increase and strengthen it by developing new aspects.

The study of IG is conducted using precise, qualitative, and exploratory methodology (Trouche et al., 2020). Initially, it involves identifying teachers' ideas about the resource, and in the final phase, studying how they actually implement it in the classroom. The classroom instance is not described here. Given the exploratory nature of this work, accessing 36 teachers is complex, and this number is considered high for this type of research.

Methodology

The methodology consists of three stages: initially, a questionnaire is used to inquire about how teachers typically teach the school knowledge involved with the resource. Then, teachers play the game, and a new questionnaire is administered to gather their opinions about the potential, advantages, and disadvantages of the game. In this stage, semi-structured interviews are also conducted with certain intentionally selected teachers to complement the information already collected. In the third stage, teachers design a possible teaching plan using the resource and implement it in the classroom.

During this phase, the process of planning the teaching, its development, is recorded, and interviews are conducted with the teacher before and after using the resource. Here, the results of the first two stages are presented. Thirty-six intentionally selected in-service mathematics teachers participated in the study. The questionnaires were designed and validated (Gazzola and Otero, 2023) and do not serve as predictive statistical instruments but rather as exploratory tools. The first questionnaire investigates what functions teachers teach, how they teach them, and with what resources. Teachers then played the game through all levels and answered the second questionnaire, evaluating the game and stating whether they would use it when teaching functions. The internal consistency of the two instruments was evaluated using the Cronbach's Alpha indicator, with $\propto=0.709$ for the first and $\propto=0.91$ for the second, both values being acceptable in the field of education.

To triangulate the information, four teachers were selected through intentional sampling (P1 to P4), and semi-structured interviews were conducted based on the following three axes: how they typically teach functions and what knowledge is important to teach; the role they would attribute to the game in teaching functions and the treatment of knowledge within it; and the advantages and disadvantages of the game concerning knowledge and its classroom use. The interviews were recorded on video, lasting between 10 and 17 minutes. The transcriptions were made using audio transcription software from videos to text and were also reviewed by the researchers.

The cases of P1 and P2, mathematics teachers based in the province of Buenos Aires, who have between 0 and 10 years of experience in the profession, were analyzed. Teacher P3 is from the province of Chaco, with 11 to 20 years of teaching experience. Teacher P4 is from the province of Entre Ríos, with 0 to 10 years of experience in the profession.

Função Resgate

Função Resgate [Rescue Function] (Gomes et al., 2022) is a video game created by the V-Lab-UFPE team with funding from the Brazilian Ministry of Education. This group developed approximately fifty games in mathematics and science to support teaching in Brazil, according to the Common National Curriculum Base (BNCC). Its objective is to help students/players develop specific skills such as analyzing functions defined by one or more sentences in their algebraic and graphical representations, identifying the domain and range, identifying growth and decay, and transforming algebraic representations into graphical ones and vice versa. Specifically, Função Resgate is oriented towards graphical and algebraic representations of certain functions, promoting the use of characteristic parameters of those functions as typically expressed in an official manner. This approach is consistent with Argentine curricular designs and regular teaching in general.

The objective of the game is to "save" marine life trapped in human waste, such as fishing nets, cans, etc. The setting represents the bottom of the ocean, where the species to be rescued are located, along with certain obstacles to be overcome, such as rocks and human waste. The location of the waste and the species to be saved varies according to the level, becoming more complex as the game progresses (Figures 1 and 2).

Figure 1 – game screen, 2nd level

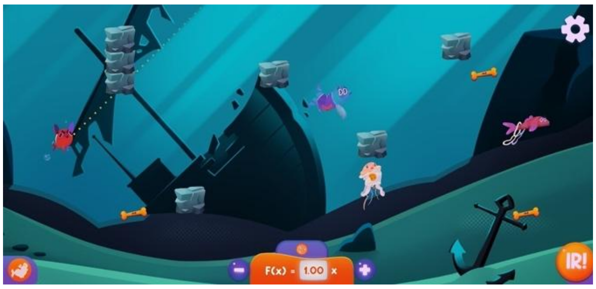
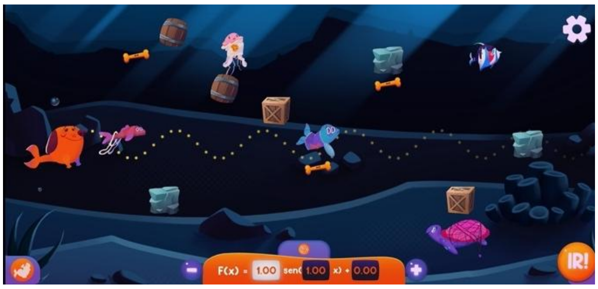


Figure 2 - game screen, 12th level



To "save" these endangered species, there is a team of heroes called *Peixorros*, each representing a specific type of mathematical function. These functions can include constant, linear, affine, quadratic, sine, cosine, exponential, logarithmic, and modulus functions. On the home screen, the game offers a section identifying each *Peixorro* and providing a brief explanation of the function it represents (an example is shown in Figure 3). The player chooses a function to use and interacts with the parameters in the algebraic representation of that function, observing the behavior of the curve in real-time to determine the path the *Peixorro* will take. In this action, the player can activate the view of the Cartesian plane to access the coordinates (x;y) where the species are located (Figure 4).

Not all functions are always available. Each level grants access to certain functions, which appear in a curriculum-established chronological order of increasing complexity (Gazzola & Otero, 2023).

Figure 3 –Description of Ameixa

Figure 4 – 'radar' activated, 7th level

The resource is free to download for IOS and Android[1]. Below, we summarize the main results of the two questionnaires administered to in-service mathematics teachers regarding their usual methods of teaching functions and their assessment of this game. We also analyze the opinions of the four teachers who participated in the interviews to gain deeper insights and better understand the findings from the questionnaires. It is important to note that this work does not analyze the phase of effective classroom implementation, which is the final stage connected to the theoretical framework.

Results of the questionnaires

A detailed description of the design, validation, and results of its application can be found in Gazzola and Otero (2023). Below, we present the answers to the first questionnaire.

[1] https://play.google.com/store/apps/details?id=br.gov.mec.vlabFuncaoResgate&hl=es_AR&pli=1

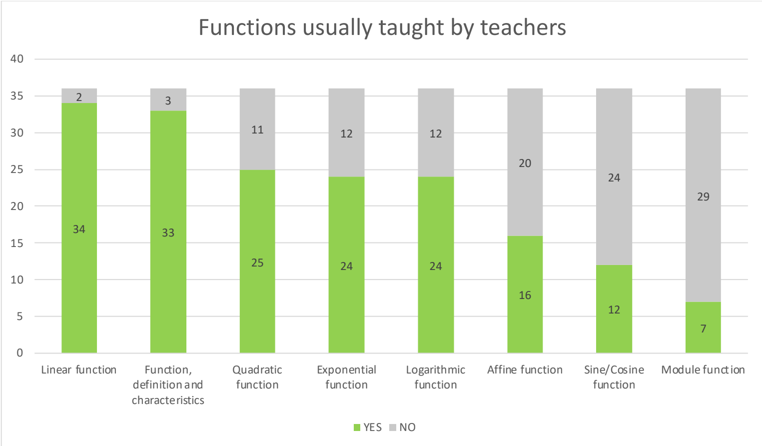


Figure 5. Functions usually taught by teachers in Argentina, in decrescent order.

Figure 5 shows that teachers predominantly teach a general notion of functions and their characteristics, along with certain specific functions. The functions most frequently taught by the surveyed teachers in secondary school are the affine function and the quadratic function. In contrast, the least taught are the transcendental functions, such as sine, cosine, and the modulus function, followed by the exponential and logarithmic functions.

Table 1 presents responses on how functions are taught. Most of the time, the teacher starts with a *'context problem'* intended to introduce (produce the encounter) the formula, and then proposes a guide that teachers describe as "theoretical-practical," which they usually develop themselves.

Table 1: How do mathematics Argentinian teachers usually teach functions?

1. The teacher proposes theoretical-practical material and the students ask their questions.	4
2. Always introduce a new function with a context problem and then the material.	22
3. The teacher and student study and research together.	3
4. The teacher proposes theoretical-practical material based on graphics such as GeoGebra.	2
5. The teacher explains, exemplifies and then the students solve similar tasks.	6

Table 2 shows the knowledge about functions that these teachers usually teach. They primarily focus on the formula for functions, the dependent and independent variables (in an absolute and stereotyped way), the notable points, the graphical representation from tables of values, the sets of positivity and negativity, and the intervals of growth and decrease. In traditional teaching, all of the above is presented ostensibly, without justification.

To a much lesser extent, the notion of parameters and their role in the characteristics of the function is taught, along with their relative nature, that is, the possibility of interchanging them with equations. Inequalities, systems of equations and inequalities, and mixed systems relative to each function are practically not taught.

Table 2. Knowledge about functions usually taught by teachers

	nothing	bit	a lot
Representation in tables and graphs made by hand.	6	9	21
Definition by formula.	9	10	17
Variables	5	10	21
Mixed systems	21	11	4
Writing the formula from the graph	9	7	20
Exchange of variables and parameters	14	10	12
Solving equations	6	13	17
Parameters	11	12	13
Obtaining notable points	9	6	21
Growth/Decrease Intervals	6	8	22
Positivity and negativity intervals	7	7	22
Inequations	21	10	5

Finally, Table 3 presents the responses regarding the resources teachers use to teach functions. Digital resources such as YouTube videos or online books, including widely used and free software like GeoGebra or spreadsheets, are rarely utilized.

Table 3. Resources used

	nothing	bit	a lot
Theoretical-practical works created by you	4	11	21
Photocopied textbooks (parts)	19	12	5
GeoGebra	12	13	11
Digital textbooks	24	5	7
Spreadsheets	28	5	3
Context problems	3	8	25
digital game	26	3	7
You-tube videos	23	10	3

The results of the second questionnaire mostly show a neutral or average assessment of the game Função Resgate and how functions are treated in the game. Teachers gave an average rating to the interest in the functions that the game promotes, the feedback it offers on mathematical knowledge, the difficulty it presents for students, and the interest generated by playing it more than once.

High ratings were primarily given to the game's interface, particularly its aesthetics and design. Regarding how the game proposes the study of functions, positive ratings were given to the definition, algebraic representation, and use of the Cartesian plane. The treatment of notable points and the role of parameters in winning the game received an average rating, while negative ratings were related to the algebraic calculations that the game promotes.

Teachers consider the most difficult functions to play and win are the harmonic and quadratic functions. Figure 6 shows the teachers' willingness to use this game.

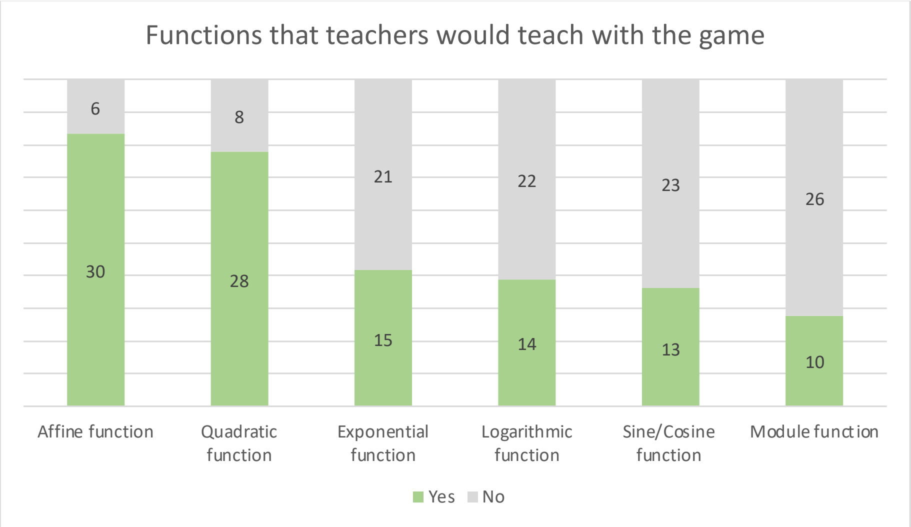


Figure 6. Functions teachers would teach with the game.

Almost all of the teachers surveyed said they would use the game in their classes, mainly to teach the affine function and the quadratic function. Regarding how teachers would use the game to teach functions, Table 4 shows that the most chosen options are related to traditional teaching. These include using the game to integrate and review once all the functions have been studied, explaining and exemplifying a function and then suggesting that the students play the game, or proposing materials with exercises that involve the game. This implies that these teachers would only use the game after teaching—as a resource for review—rather than as an integral part of the teaching process.

Table 4. How would you use the game to teach functions?	**f**
1. I would propose a material that defines the function as in the game and then the students play.	0
2. I would explain the function, exemplify and then the students play.	2
3. I would have the students play and then propose a practical theoretical guide without returning to the game.	1
4. I would have the students play and then propose a practical theoretical guide with GeoGebra without returning to the game.	3
5. I would propose a material where exercises that involve the game are proposed.	8

6. I would use the game to integrate and review, once all the functions have been studied.	8
7. I would use the game as part of teaching where the teacher and the student investigate and study together.	14
8. I wouldn't use it.	0

Interview results

The four teachers interviewed have different positions regarding the use of games in the classroom, which we summarize below. Teacher P1 holds a negative opinion, which extends beyond Função Resgate to any resource based on games. During the interview, she repeatedly made pejorative allusions to games, considering them far removed from any teaching and learning process.

Teacher P2, on the other hand, views games as an opportunity for change and believes they can be adapted to different years of secondary schooling. She has even used them in her courses. Teacher P3 also holds a positive opinion, but in her case, she overvalues any digital resource, considering them valuable regardless of their characteristics or scope. Finally, Teacher P4 refrains from making positive or negative comments about the game, maintaining a neutral stance, possibly due to uncertainty regarding this new resource.

Although in the second questionnaire all teachers stated that they would use the game in their classes, the interviews reveal certain nuances. The use of the game is almost exclusively limited to the idea that using a game in class motivates students. This motivation is not related to mathematical knowledge but rather to entertainment and willingness to participate. In summary, P1 acknowledges in the interview that she would not really use the game. P2 and P4 would only use it once all the functions have been studied, expressing that it lacks sufficient theoretical explanations, and they would use it for review or as a closing activity. P3 mentions that he would propose activities involving the game, but when asked for specifics, he admits not knowing how to do so.

Regarding mathematical knowledge, the four teachers highlight the game's potential to show how graphs are modified when parameters are varied, in line with usual teaching based on ostensive identifications. Although they recognize the involvement of parameter variation, they dismiss the importance of understanding how these variations affect the graph to play and win. The teachers place excessive importance on the visualization of the graphical representation. For example, P2 notes that having the graphs to look at saves time, considering it faster (and therefore better) to view the graphs from the game than to create them manually or using software where formulas and data must be preloaded.

Regarding the parameters, P1 criticizes the game for not allowing specific values to be chosen for them, as the variations between two values within the game follow an implicit criterion established by the software. P2 and P4 also mention that some harmonic functions are not complete and that some parameters are not considered. Neither of them analyzes the possible didactic reasons behind this. Finally, none of the teachers interviewed referred to the algebraic representations proposed in the game, such as the fact that only certain representations are used and not others, like the quadratic function, which is only expressed in polynomial form.

All of the above is related to the usual school method of teaching functions, which is based on defining the function by a formula, drawing its graph, and highlighting certain notable points described ostensibly. In school, it is not common to carry out an appropriate study of the parameters, as the analysis of possible function families is often neglected, and consequently, only some of them are addressed. This is the case with P3, who only teaches the polynomial form of the quadratic function and only analyzes the main coefficient, considering cases where it is greater or less than zero.

The four teachers interviewed believe that the game is won by "trial and error" rather than by what they consider mathematical knowledge. This is due to an inappropriate conception of learning that only considers the predicative aspects of knowledge, according to which the students' actions (operational form) are not considered mathematical knowledge. This is contrary to the instrumental approach based on the ideas of Vergnaud (2013), who considers the operational and predicative forms inseparable in the construction of all knowledge.

Conclusion

In this work, we carry out two key phases for analyzing the instrumental genesis of a group of in-service mathematics teachers related to the potential use of the digital game Função Resgate. We use complementary qualitative instruments such as questionnaires and semi-structured interviews to describe the relationship between the traditional way of teaching functions and the value that teachers assign to the game as a teaching resource. These ideas influence the patterns of resource use when teaching.

Functions are taught in a sequence that involves proposing a formula as a definition, obtaining a graphical representation, and identifying certain notable points that can be recognized and ostensibly justified from it. This way of conceiving mathematical knowledge, which only considers its predicative form and leaves aside the operational form, supports an epistemological conception of mathematics and a deeply-rooted way of teaching functions that can make it difficult to leverage the game's enormous potential and the mathematical activities it would facilitate. In summary, teachers express a certain reluctance to use digital games in the classroom, as it is a resource they have never used and does not align with traditional teaching methods.

In this sense, the third stage of the research, which is currently being developed, would help teachers incorporate games as an instrument that enables them to take advantage of the enormous potential of digital games in teaching. This would be achieved by experiencing the positive results of their introduction in the classroom, which they are currently unaware of a priori.

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