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TEACHING AFFINE FUNCTIONS: EVALUATING THE USE OF GAMES WITH AUTOMATIC FEEDBACK IN GEOGEBRA

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Abstract

This work is an excerpt from doctoral research, in development, and aims to evaluate games with automatic feedback, for the teaching of affine functions, through the GeoGebra software. Using the fundamentals of gamification, which consists of using elements of a game in situations that are not necessarily a game, to promote better learning and improve students' levels of engagement and motivation. Based on Raymond Duval's theory of Registers of Semiotic Representation, it is expected that the student will be able to understand and assimilate the content in order to identify the different types of register of an affine function, such as its textual, tabular, algebraic or graphic form. A workshop was offered to four students of the 9th grade of elementary school of a private school in São Paulo, Brazil, to verify the use of the games and possible improvements that can be implemented according to the feedback of the participants. Such activities will be applied, in the future, with other students, for the collection and analysis of study data. All the games developed have automatic feedback, that is, the student receives feedback from the system after answering a certain question. If the answer is correct, there will be encouraging feedback congratulating for completing the activity. If the answer is incorrect, other feedback, according to each possible error, previously predicted, to provide clues that allow the student to identify his error, make new conjectures and try again to solve the question. In an interview with the subjects of the workshop, two participants reported that they had no previous knowledge on the subject and two others stated that they had superficial knowledge. Of the nine available tasks, seven were successfully solved. The automatic feedback provided allowed the students to progress in the activities, each one at their own level and time, according to the new knowledge they were acquiring. All stated that they enjoyed learning by playing games and that this feature is a fun and different way to study. They claimed that the main difficulty was that they did not know the content beforehand and that some issues they did not know how to solve. It should be emphasized that the activities will be applied to future subjects, such as a diagnostic evaluation after the approach to the content, and that the initial applications will allow new possible improvements.

Keywords: *Gamification, digital technologies, mathematics education, affine function, GeoGebra.*

1. Introduction

With the technological advancements increasingly integrated into our daily lives, the implementation of new pedagogical practices in the classroom that incorporate the use of digital resources becomes essential. According to Barbosa, Pontes, and Castro (2020), the use of technology in the classroom enables teachers to stimulate student learning. Silva and Abar (2023) report that a technological approach in an educational context, utilizing gamification techniques, promotes motivation and increases student engagement levels.

Zichermann and Cunningham (2011) define gamification as a process of thought and game mechanics aimed at engaging individuals and solving problems. Deterding (2012) further informs that the concept of gamification is not based on creating a complete game, but rather on using game design elements in non-game contexts to motivate specific behaviors. Conversely, Busarello (2016) defines gamification as a system that employs game elements to solve problems, aiming to increase individual engagement and stimulate intrinsic motivation through playful environments capable of exploring extrinsic motivation.

According to the National Common Curricular Base - BNCC (Brasil, 2018), the use of dynamic geometry software plays an important role in understanding and applying mathematical concepts. GeoGebra software presents itself as an excellent didactic tool, as it is a dynamic geometry software, free, available for download on both computers and smartphones, and can also be accessed online. It can be used for any level of education, integrating geometry, tables, and graphs into a single platform, and allowing students to manipulate mathematical objects during their understanding (Instituto GeoGebra São Paulo, 2014).

The visualization of various types of representation records in a single application provides a better understanding of the topic being addressed. According to Damm (2008), in the teaching of functions, when studying their graphs, tables, and equations, we understand the partial records of the mathematical object, and when combined, they enable its complete understanding. The author further explains that only when the student can transition between different types of records of the same mathematical object naturally can we say that their learning is meaningful.

Combined with all these resources, it becomes important to develop a feedback system in the creation of a gamified activity that allows the student to learn from their mistakes. According to Narciss (2008), feedback consists of all post-response information provided to the student to inform them about their real learning or performance state, becoming a powerful factor in the learning process, especially in a digital environment. Shute (2008) states that formative feedback enables identifying the level of difference between the student's performance and the desired level, reducing the gap between them and reducing the student's uncertainty about their performance in a particular activity.

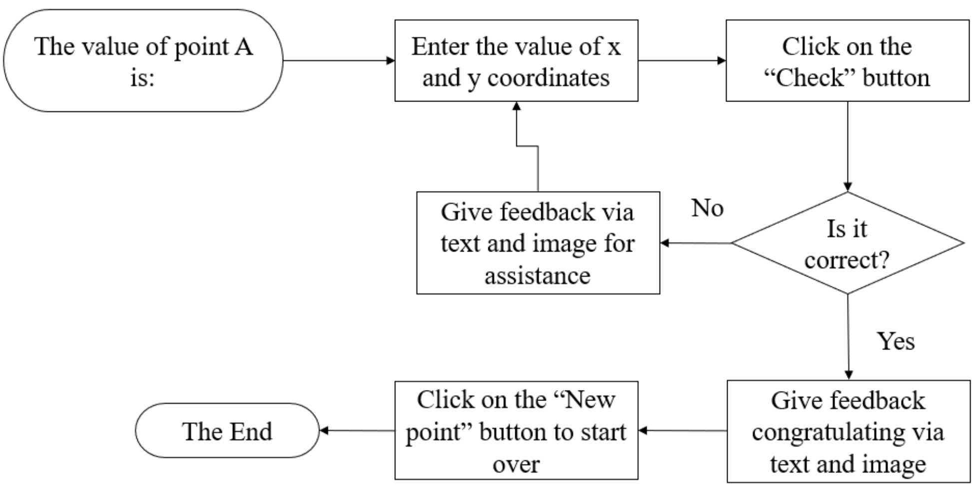
Based on the above, the objective of this work, a segment of an ongoing doctoral research, is to verify the applicability of games with automatic feedback, developed in the GeoGebra software, for teaching linear functions, based on Raymond Duval's Theory of Registers of Semiotic Representation, enabling students to understand the various forms of representation of the studied mathematical object and properly perform the conversion between them.

2. Materials and methods

Four students aged 14 from the ninth grade of Elementary School from a private school located in São Paulo, Brazil, participated in the research. The activities were carried out in the school's computer laboratory, and the subjects had one hour to complete them. The students were provided with the webpage address they should access and then the access password so they could start the game.

The developed games were based on Raymond Duval's Theory of Registers of Semiotic Representation. The chosen mathematical object for their construction was the study of Linear Functions. In this context, nine games with automatic feedback were developed in the GeoGebra software and were arranged in the form of a task in GeoGebra Classroom. The presented sequence was designed for the subject to perform in order, although the students played them randomly. For each game, a flowchart was created detailing each stage of its construction, as exemplified in Figure 1.

Figure 1. Example of the construction of one of the games.



In all games, students could relate to the different types of records of the studied mathematical object, performing various conversions so they could mobilize their knowledge for a more meaningful learning experience. Different types of records, such as textual, algebraic, tabular, and graphical, were addressed in a way that allowed students to perform the necessary conversions and observe the linear function in different forms. For each type of mistake, specific feedback with tips was developed to guide the student in understanding their mistake and overcoming obstacles, as shown in Figure 2.

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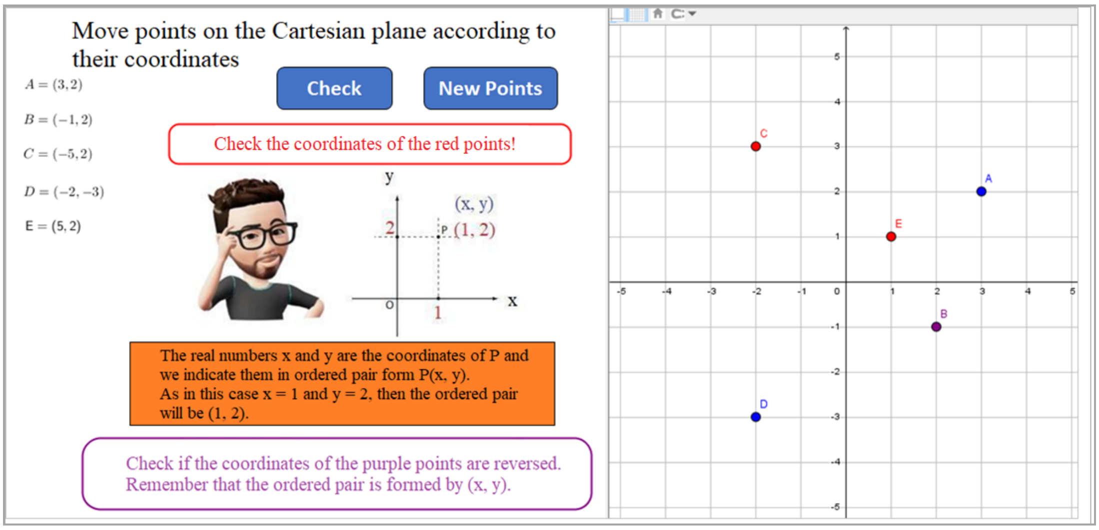
Figure 2. Example of feedback in one of the games.



3. Results

The objectives and types of records addressed in each game are presented in Table 1.

Table 1. Objectives and types of conversions addressed in each game.

Game	Objective	Conversion of Records
1	Understand the concept of a function	Algebraic → tabular → graphical
2	Identify coordinates of a Cartesian point	Graphical → algebraic
3	Position points in the appropriate location on the Cartesian plane	Algebraic → graphical
4	Determine the function from a problem	Textual → algebraic
5	Find the corresponding ordinate of the abscissa	Algebraic → tabular → graphical
6	Determine the line corresponding to the function	Algebraic → graphical
7	Find intersection of lines	Algebraic → graphical
8	Analyze characteristics of line coefficients	Algebraic → graphical
9	Identify values of line coefficients	Graphical → algebraic

The initial games, which focused on Cartesian points and were the easiest ones, were completed by all participants. The level of difficulty increased, as players progressed through the tasks. Among the nine games provided to the students, seven were successfully completed by at least one of the students. Only games 6 and 7 were not completed by any student. Both games have the same dynamics, but while in game 6 the student works with only one line on the Cartesian plane, in game 7 they need to manipulate two lines. Since the tasks were performed individually by the students, and half of them had no knowledge of linear functions while the other half had only basic knowledge, it may have caused doubts about how to carry out the activity. Perhaps with the guidance of a teacher, they would have been able to complete the tasks.

In game 8, developed in three phases, the first two phases separately examined the characteristics of the slope and y-intercept coefficients and how their values influence the behavior of the line's graphical representation. In the final phase, the student analyzed their values simultaneously. This game was designed as an introduction to the next game. Game 9, which was the most comprehensive, was played only by one student; the others did not get to play it, perhaps due to limited time or being engrossed in the previous games.

It is worth noting that the proposal, when developing the games, is for them to be applied after the student has learned the mathematical content and for their application to be considered as a diagnostic assessment to verify if the individual can learn from their mistakes, make conjectures, and attempt again correctly. The students who participated in this experiment played without any prior explanation of the content.

At the end, the students responded to a questionnaire about the activities carried out, expressing their main difficulties and their opinion on learning mathematics through games. The questionnaire consisted of seven questions:

1) Did you have any prior knowledge about linear functions?
2) Were you able to complete the activities after the automatic feedback?
3) Were you able to learn by playing alone?
4) What was the biggest difficulty?
5) Did you enjoy learning this way?
6) Would you change anything in the games you participated in?
7) Were there any activities you couldn't complete? Why?

When asked about their level of knowledge on the topic, half of the students indicated they had no prior knowledge, while the other half reported having basic knowledge previously studied. Regarding the feedback, all of them mentioned that the hints provided by the games when they made mistakes helped them to reformulate their answers and get the questions right. One student mentioned having a bit of difficulty, and another stated they couldn't complete the tasks due to their level of knowledge. All of them stated they were able to learn by playing and that not knowing the content completely or not knowing what to do in certain games were the main difficulties. Concerning learning through gaming, all of them expressed enjoyment in engaging in activities this way, considering it an ideal tool for learning, using words like "interesting," "practical," "fun," and "engaging" to describe the experiment. When asked if they would change anything in the games, only two students provided suggestions; one would include more examples to facilitate understanding, and the other requested more explanations (this student had no prior knowledge of the topic). Regarding the activities they couldn't complete, they cited lack of knowledge on the subject, time constraints, or not understanding what was required as reasons.

4. Conclusions

By introducing games into mathematics learning, we enable students to learn in a different and enjoyable way, sparking their interest in the subject and enhancing their levels of motivation and engagement. The proposal to develop games with automatic feedback allows students to learn from their mistakes instantly, enabling them to correct them and thus quickly resolve their doubts. Even with limitations regarding the content covered, the unanimous response was that everyone enjoyed learning through gaming. Gamification proves to be an important tool using technological resources that significantly impact performance and interest in studying mathematics. All the difficulties and suggestions provided by the students have been taken into consideration for the improvement of the games, ensuring their successful application in future research endeavors.

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