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GeoGebra in Moodle: enhancing mathematical learning in the digital environment

André Nagamine[1]
[1](DCET, Universidade Estadual do Sudoeste da Bahia, Brasil)

Abstract:
GeoGebra is a software widely used in the teaching and learning of Mathematics. It facilitates the creation of educational activities and the conversion between semiotic representations. However, its use is often restricted to installed versions of the software. This article aims to demonstrate how the integration of GeoGebra with Moodle can significantly expand its applications in the educational context. For analysis purposes, a GeoGebra applet was developed. The study is based on Rabardel's Instrumental Approach and Duval's Theory of Registers of Semiotic Representations. This theoretical foundation provides an in-depth perspective on the use of the software in teaching Mathematics. The integration seeks to enhance mathematical learning in the digital environment. The combination of these technologies offers new pedagogical possibilities. The article explores the potential of this combination to improve the teaching process
***Key Word**: GeoGebra; Moodle; Registers of Semiotic Representations.*

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I. Introduction

Developed by Markus Hohenwarter between 2001 and 2002 at the University of Salzburg, Austria, GeoGebra has established itself as one of the most widely recognized and utilized mathematical software globally. Its structure offers diverse possibilities for interaction with mathematical objects, fostering the construction of distinct scenarios and approaches for teaching and learning. Among its capabilities, the creation of interactive applets stands out, enabling dynamic educational environments that integrate multiple mathematical representations in an interconnected and interactive manner.

The GeoGebra website extends beyond a mere site dedicated to the software; it functions as an online platform where users can access not only the web version of GeoGebra's various windows but also a vast repository of materials organized by theme, available for download. Additionally, the platform allows users to create a personal account, facilitating the construction of a personalized environment where they can store materials of interest, save content from other users, develop their own resources, organize folders, create interactive activities, produce e-books, and even manage virtual classrooms. Among the materials that can be developed on the platform, applets are particularly noteworthy. In a broader sense, applets (Java applets) are programs developed in the Java programming language that can be embedded in HTML code (Deitel, 2003). In the context of GeoGebra, applets are applications that operate within other programs, such as web browsers, and are distributed as files with the ".html" extension, allowing their use without the need for prior installation of the GeoGebra software.

With the advent of the Covid-19 pandemic in Brazil in 2020, the demand for Learning Management Systems (LMS) increased considerably. According to Oliveira (2020), these systems consist of educational software platforms designed to centralize the management and distribution of online courses, offering a dynamic virtual environment where educators can structure and provide didactic content, facilitate communication and collaboration among students, administer assessments, and monitor both individual and collective performance. Thus, LMS aims not only to optimize the teaching-learning process but also to enable a more personalized educational experience tailored to each student's needs.

Among the various educational platforms available, Moodle (Modular Object-Oriented Dynamic Learning Environment) stands out as an open-source LMS developed to offer institutions, administrators, and students a diverse, flexible, and secure online learning environment. Its primary objective is to enable the creation and delivery of personalized online learning experiences. According to Moodle (2025), the platform was developed by Martin Dougiamas in Australia and was effectively distributed starting in 2003. Currently, its global user community comprises thousands of individuals, including teachers, students, system administrators, instructional designers, and programmers across various countries, solidifying its position as one of the most widely adopted educational platforms worldwide.

Moodle provides a wide range of resources and activities that can be combined in different ways to compose a dynamic, interactive, and efficient online learning environment, adapting to the specific needs of teachers and students, regardless of the discipline. Among the most relevant functionalities offered by the platform, those focused on interaction and assessment play an essential role in constructing more participatory instruction. These tools notably include: Assignments, Forums, Lessons, and Quizzes. Although frequently used for evaluative purposes, these activities also enable the creation of spaces for discussion, collaboration, and debate, promoting the exchange of ideas and the deepening of knowledge among participants.

In this context, the present article aims to analyze the integration between GeoGebra software, and the Moodle learning platform, exploring its potential to enhance the teaching and learning process in mathematics. According to Santos dos Santos and Trocado (2016), the first technical implementation of this integration occurred in 2009 with the development of a plugin that enables the embedding of GeoGebra applications within Moodle. This integration allows teachers to create GeoGebra applets directly in Moodle, leveraging their advanced functionalities for developing interactive assessment activities. In essence, the convergence of these two educational technologies significantly expands the pedagogical possibilities of both, providing an innovative and dynamic environment for those seeking to improve mathematics education.

II. Theoretical Framework

In the context of educational technologies, both LMS, such as Moodle, and GeoGebra software can be understood as technological tools that support teaching and learning. However, for these tools to become effective instructional instruments, it's crucial to comprehend the process of pedagogical appropriation they undergo. To that end, this study is grounded in Rabardel's (1995) Instrumental Approach, which investigates the transformation of artifacts into instruments within an educational context.

Concurrently, GeoGebra stands out for its ability to represent the same mathematical object through different semiotic representations, providing a richer and more interactive learning experience. In this regard, understanding the role of mathematical representations in the teaching and learning process is based on Duval's (1995) Theory of Semiotic Representation Registers, which emphasizes the importance of conversion and articulation between different forms of representation for the construction of mathematical knowledge.

Instrumental Approach

Rabardel's Instrumental Approach, rooted in the theory of cognitive ergonomics, refers to the manipulation, incorporation, or employment of technological tools, transforming them into instruments for scientific investigation, pedagogical practice, and the learning process.

The foundation of this theory lies in the premise that a tool (e.g., Moodle/GeoGebra), referred to by Rabardel as an artifact, does not automatically constitute an effective and functional instrument on its own. The effectiveness of a tool depends on its suitability for its specific intended purpose; some prove more appropriate than others, depending on the nature and requirements of the foreseen use. This principle extends equally to the educational context, particularly concerning the incorporation of learning platforms and software into the teaching and learning process.

We consider the instrument as something constructed by the individual throughout a process we call instrumental genesis.

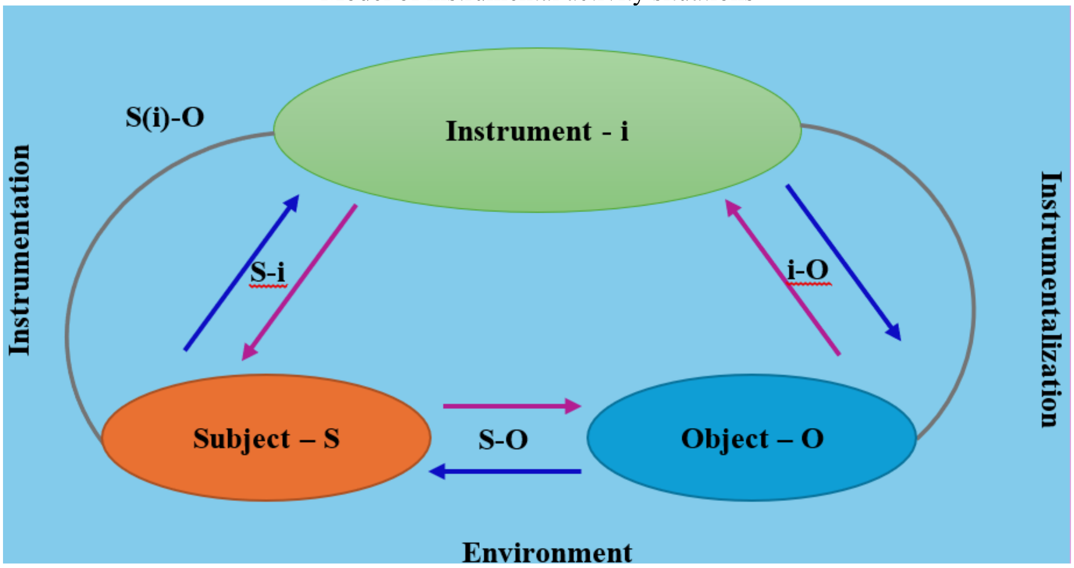
This concept also applies to any other object that functions as a tool (in our case, a didactic one), such as a computer or software. The learning process through which an artifact progressively becomes an instrument is termed instrumental genesis (Henriques, Attie, Farias, 2007).

This process of transforming an artifact into an instrument describes the situation in which the instrument is utilized. The model is structured around three fundamental components:

- The subject, who can assume different roles and is responsible for directing psychological action toward the object.
- The instrument, which can be manifested as a tool, machine, or product, serves as a mediator between the subject and the object.
- The object, which can be concrete material, a target of activity, or even abstract concepts, constituting the element upon which the action is effectively exerted.

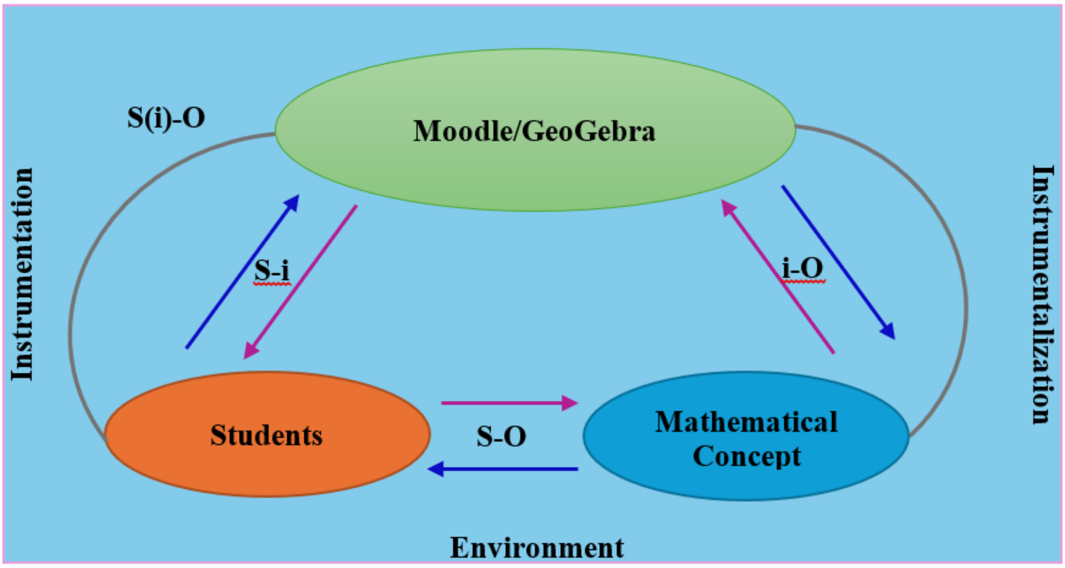
In this context, Rabardel (1995) proposes the SAI (Situations of Instrumental Activities) model, illustrating the relationships between the subject and the object, mediated by the instrument. The SAI model (Figure) highlights the interactions involved in instrumental activities: subject-object [S-O], subject-instrument [S-i], instrument-object [i-O], and subject-object mediated by the instrument [S(i)-O]. These interactions unfold within an environment shaped by the set of conditions the subject must consider to carry out their activity.

Model of instrumental activity situations



Following Rabardel's proposed model, we can apply his approach by analyzing instrumental activities, considering the relationships among the subject, the instrument, and the object upon which the subject acts. This analysis allows us to understand how these elements interrelate within the proposal presented in this article. In Figure below, we present an adaptation of this perspective, highlighting the interaction between the fundamental components involved in the process.

Model of instrumental activity situations for the article's theme



Semiotic Representation Registers

We emphasize the relevance of Raymond Duval's Theory of Semiotic Representation Registers in the process of learning mathematics. This theory highlights how coordination between different registers is essential for constructing conceptual knowledge and solving problems. In this context, GeoGebra can be analyzed from this perspective, as it is software that allows the visualization and manipulation of multiple representations of the same mathematical object. This capability fosters the articulation between different registers and enhances the understanding of mathematical concepts.

According to Duval (2003), for a semiotic system to be considered a representation register, it must allow for three fundamental cognitive activities linked to semiosis:

- Formation of a representation identifiable as a representation of a given register. The formation of a representation involves selecting relationships and data from the content to be represented, based on the formation rules of the cognitive register. These rules ensure the identification and recognition of the representation, as well as its use for treatments.

- Treatment of a representation, which is the transformation of this representation within the same register where it was formed. Treatment is an internal transformation within a register. There are specific treatment rules for each register, such as rules of derivation, thematic coherence, and associative rules of contiguity and similitude.
- Conversion of a representation, which is the transformation of this representation into a representation in another register, preserving all or only a part of the content of the initial representation. Conversion is a transformation external to the starting register. Conversion requires perceiving the difference between the meaning and the reference of symbols or signs.

Examples of semiotic representations include a geometric figure, a statement in natural language, an algebraic formula, a graph, or written notation and symbols. Duval argues that understanding mathematical objects is intrinsically linked to semiotic representation, as these objects are not directly accessible through intuitive perception. As Duval (2003) states, "[...] mathematical objects should never be confused with the representation one makes of them." The ability to manipulate and coordinate different representations is essential for mathematical thinking. This coordination helps differentiate the mathematical object from its various representations.

It is fundamental to emphasize that learning does not occur exclusively through the different representations of an object of study, but rather through the conversion between these representations, which enables the effective construction of knowledge. For the comprehension of mathematical concepts, it is not enough to simply have multiple semiotic representation registers available; the coordination among them is also indispensable, an aspect that plays a central role in the cognitive process. The ability to move between distinct registers constitutes a necessary condition for learning. According to Duval, there is a diversity of representation registers for the same mathematical object, and the articulation between them is a condition for understanding in mathematics. In other words, the mere diversity of registers is not sufficient to guarantee the assimilation of concepts; it is essential that an articulation occurs between them, allowing the subject to recognize the same mathematical object under different forms of representation. This interrelationship between registers proves crucial for the construction of mathematical knowledge.

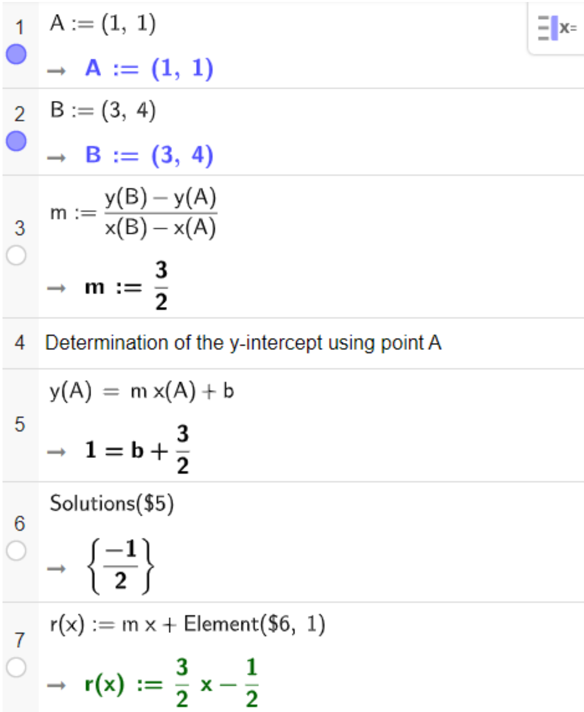
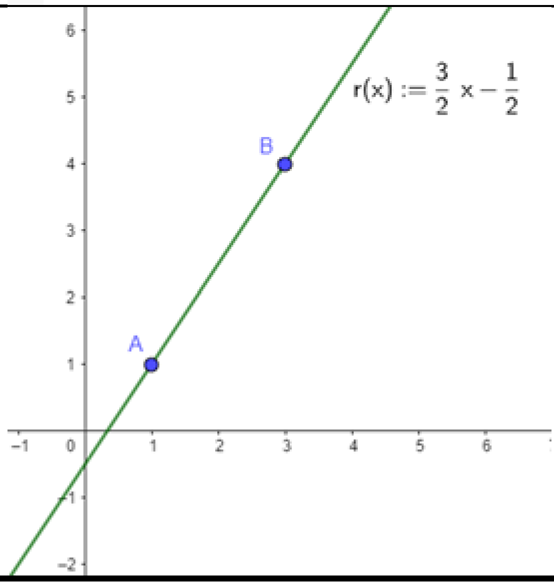
Duval identifies four distinct types of registers, categorized into two broad classes: discursive representations and non-discursive representations, as presented in Table below.

	Discursive Representation	Non-Discursive Representation
Multifunctional Registers: Treatments are not algorithmizable	**Natural Language** **Verbal** (conceptual) associations. Forms of reasoning - Argumentation based on observations of beliefs. - Valid deduction from definitions or theorems.	**Geometric or Perspective Figures** Operative apprehension, not solely perceptive; Construction with instruments.
Monofunctional Registers: Treatments are mainly algorithms	**Writing Systems** Numerical (binary, decimal, fractional); Symbolic (formal languages).	**Cartesian Graphs** Change of coordinate systems;; Interpolation, extrapolation.

To illustrate the variation between different representation registers enabled by GeoGebra, let's consider the following mathematical object:

The equation of the line passing through points (1,1) and (3,4) in the Cartesian plane.

Starting from the problem's description in natural language (verbal register), we utilize GeoGebra to develop its algebraic representation, exploring the features of the CAS window of the software. In this environment, it was possible to perform the necessary sequence of calculations: initially, we defined the points on the plane; subsequently, we determined the slope of the line; and finally, we applied the information from one of the points to find the y-intercept of the line's equation. Simultaneously, in the graphic window, the construction of mathematical objects occurs dynamically, allowing for the instantaneous visualization of the graphical representation as the calculations are executed in the CAS window.

<table>
<tr><td>Natural Language</td><td>Equation of the line passing through points (1,1) and (3,4) in the Cartesian plane</td></tr>
<tr><td>Algebraic register</td><td>
</td></tr>
<tr><td>Graphical register</td><td>
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This interconnection among the different representation registers — verbal, algebraic, and graphical — highlights GeoGebra's potential to foster a more integrated and meaningful mathematical learning experience. In the table above, we emphasized each of these steps and their respective representation registers.

III. Procedure methodology

With the advancement of educational technologies, the integration between different platforms has become a fundamental aspect for enhancing teaching and learning. In this context, Moodle, one of the most widely adopted virtual learning environments, and GeoGebra, a dynamic mathematics software, can be combined to provide a more interactive and engaging teaching experience. Given this perspective, the following question arises: how can this integration be implemented, and what benefits does it offer for students and teachers? Exploring this union between the two tools allows not only for the diversification of pedagogical practices but also for the development of a more dynamic learning environment, fostering a more significant understanding and application of mathematical concepts.

GeoGebra could be embedded into the Moodle environment following the integration of scripts written in JavaScript and Python.

The first integration of GeoGebra files in Moodle happened in 2009. The filter was created thanks to the work of Sara Arjona, Florian Sonner, and Christoph Reinisch with the collaboration of the Catalan Association of GeoGebra. The GeoGebra Moodle plugin allows the incorporation of GeoGebra activities in Moodle and saves its state […] (Santos dos Santos & Trocado, 2016).

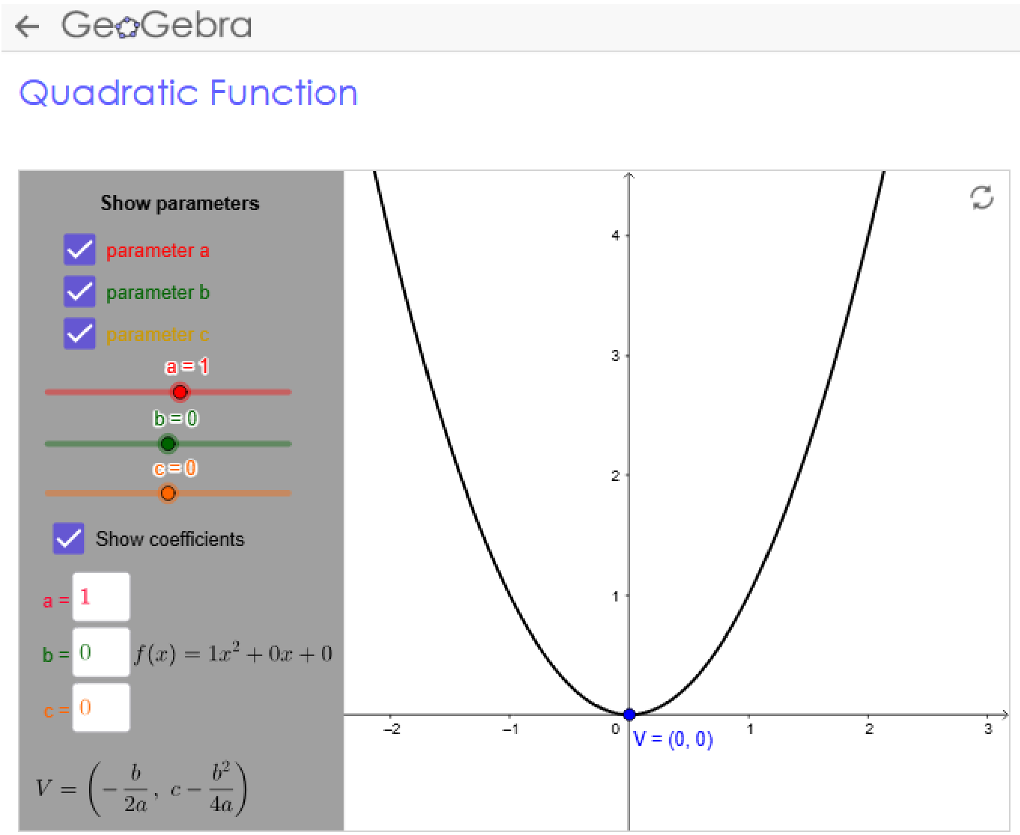
Santos dos Santos and Trocado (2016) indicate that the integration between Moodle and GeoGebra initially occurred through the creation of a plugin which, when installed in Moodle, allowed GeoGebra files to be incorporated as part of the activities available on the platform.

Currently, this integration can be achieved more directly, without the need to install additional plugins on the Moodle server. This is possible by embedding GeoGebra applets using HTML code, which significantly simplifies the process. Below, we will describe the procedure for this implementation and present some examples of activities that can be proposed.

The first step involves accessing the GeoGebra website (www.geogebra.org) and creating a user account. This registration is essential as it enables the creation and storage of materials that will be exported to Moodle. Within the GeoGebra platform, a wide variety of didactic resources can be developed, such as interactive applets, tutorials, dynamic activities, exercise lists, and e-books, in addition to the possibility of importing materials from other users. The environment offers the option to organize these materials into folders, facilitating their structuring and subsequent use.

After creating the user account, let's consider the scenario that involves developing a GeoGebra applet within the platform's workspace, configured according to the specific objectives of the activity intended for integration into Moodle. In Figure below, we present an example of a GeoGebra applet designed for exploring quadratic functions, allowing for the manipulation and analysis of their defining coefficients. This approach facilitates a deeper understanding of the function's properties, promoting dynamic and immediate visualization of the effects of coefficient variations on the corresponding graph.

Example of a GeoGebra Applet



Once the activity is created, the export process to Moodle is quite simple and intuitive. In the upper right corner of the page interface, simply select the share button (Figure below)

Activity Share Button

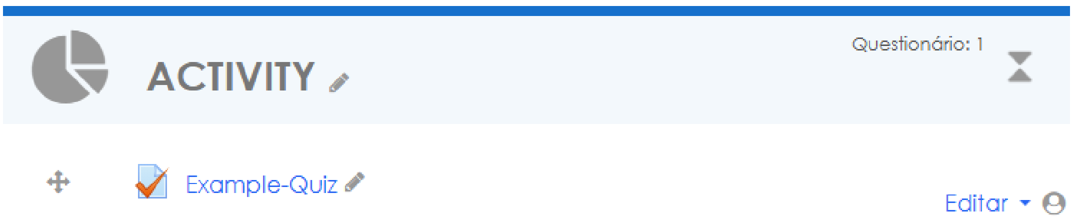
In the window that opens, we click on the "</> Embed" tab, and then simply copy the code presented in the window (Figure below).

Window with the code to export the activity to Moodle

With the code copied, the next step is to insert it into the Moodle environment. Before doing so, however, it is crucial to analyze the objectives of the activity to be implemented, as the choice of Moodle resource type will depend on the desired pedagogical proposal. For this example, we will use Moodle's "Quiz" resource, which allows for the creation of a wide variety of interactive questions. To illustrate the practical application of this functionality, we will consider two specific question types: one multiple-choice and one embedded answer (cloze), demonstrating how GeoGebra can be effectively integrated into the assessment process within the platform.

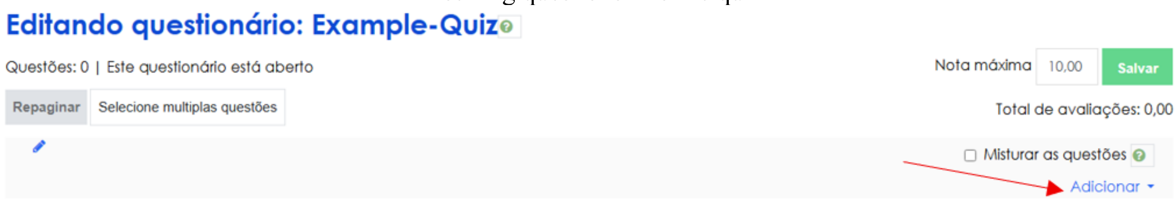
In the Moodle environment, after defining the appropriate location for inserting the activity, we proceed with the creation of the quiz, which we have named "Example-Quiz" (Figure below). Subsequently, we carry out the usual configurations for this type of activity, including identification, opening and closing periods, grading criteria, layout organization, and feedback options.

Example Quiz in Moodle



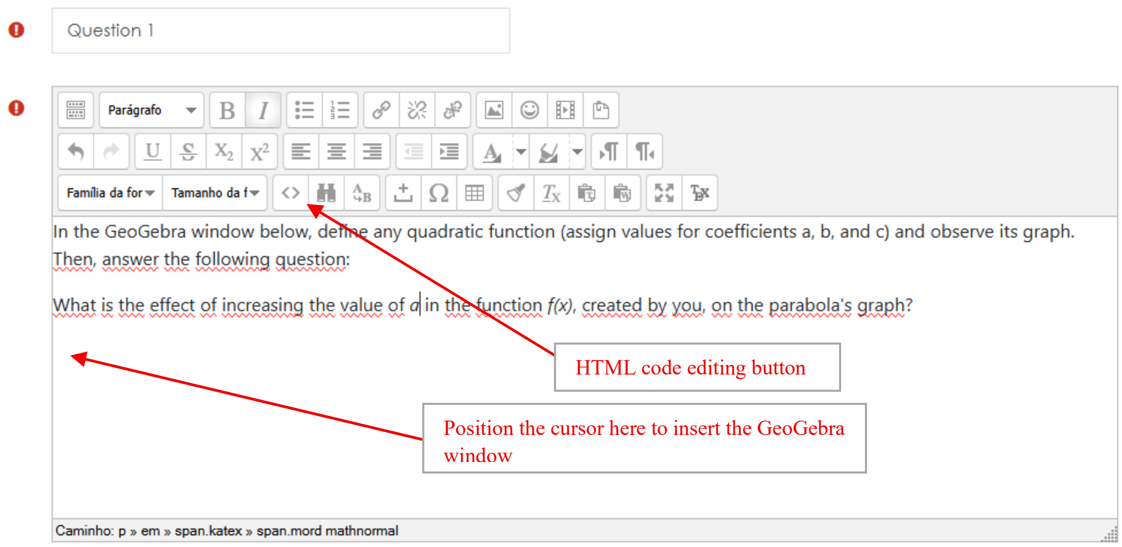
Upon entering the quiz, in the window that opens, we need to insert the questions. To do this, we click on "Edit quiz" and then on the "Add" link.

Inserting questions into the quiz



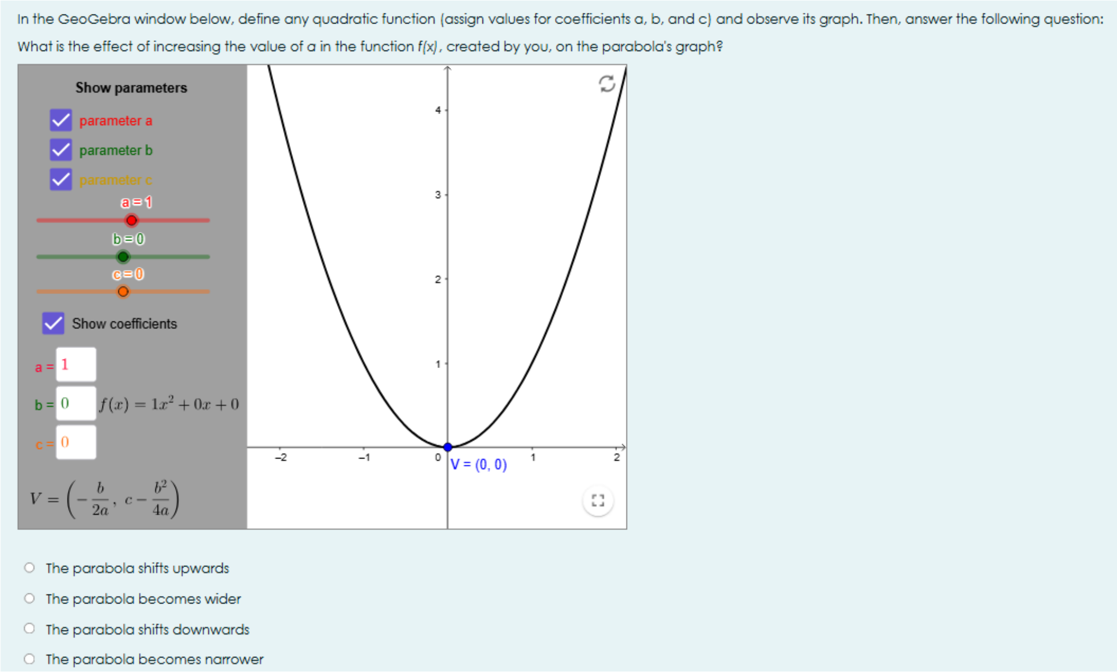
After selecting the question type, the next step is to insert the GeoGebra window as part of the problem statement. To illustrate, let's consider a multiple-choice question. Upon accessing the question configuration window, several fields will be available, with the main one being the "Question text" field, as this is where we will insert the applet. We begin by typing the question text and defining an appropriate location for incorporating the GeoGebra window. In the example illustrated in the Figure below, we position the cursor at the exact point where the interactive window will be inserted, ensuring that the visualization and interaction with the applet occur in an integrated manner with the question statement.

Embedding the GeoGebra Window



Next, we click the HTML code editing button to enable the insertion of the HTML code generated from the activity created on the GeoGebra website. After pasting the code, we complete the remaining fields in the question configuration, including defining the answer options. With this, the question is finalized, and the interactive GeoGebra window is incorporated into the problem statement. The result of this configuration can be observed in Figure below.

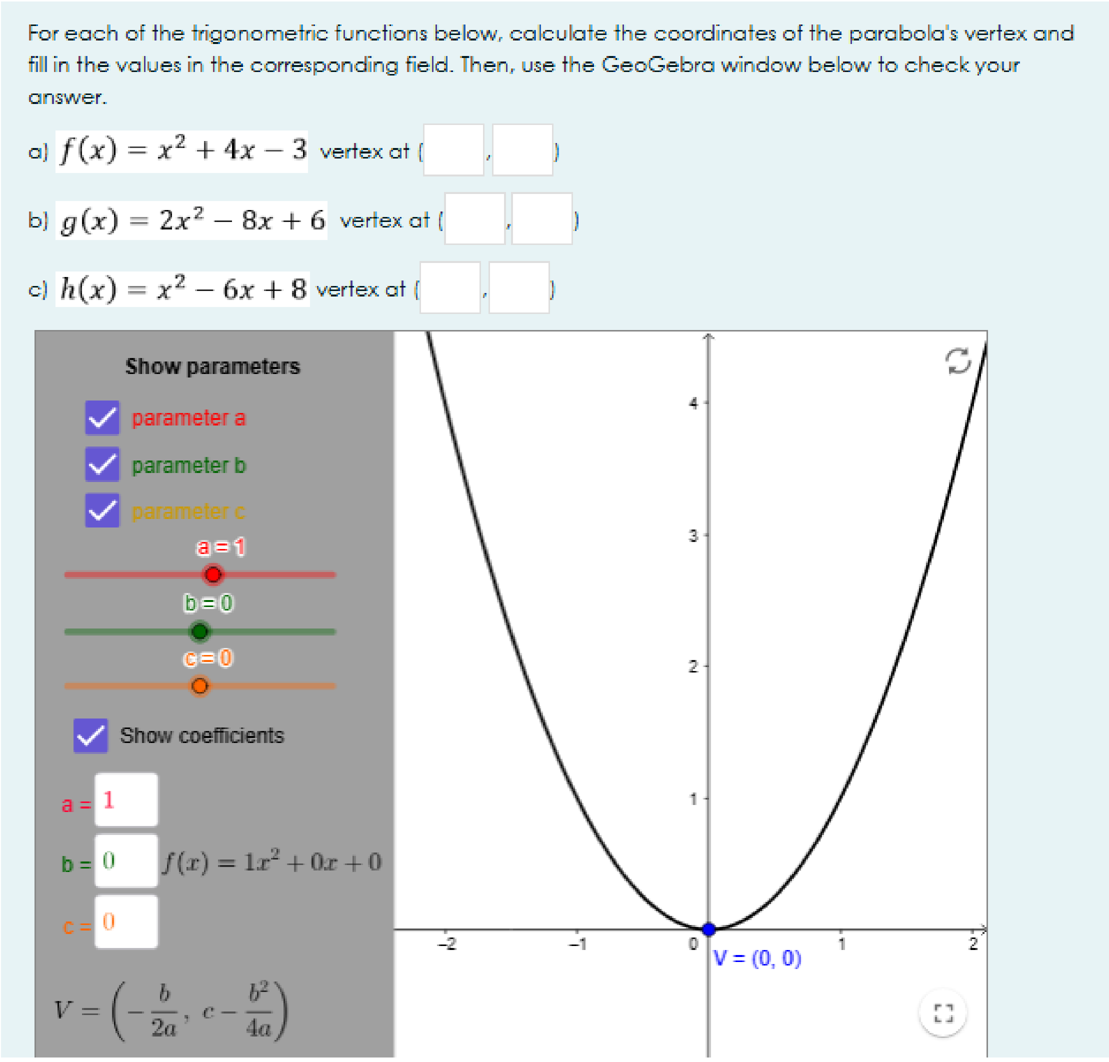
First example of a moodle question with GeoGebra applet



In the window illustrated in the Figure above, it is important to highlight that the user has full interaction with all available functionalities, exactly as if they were operating directly in GeoGebra. Furthermore, as the activity is embedded within the Moodle quiz environment, it is possible to leverage all the platform's functionalities geared towards this type of assessment. This includes automatic grading of responses, generation of personalized feedback, assignment of grades, as well as sending and receiving messages, providing an interactive and efficient environment for teaching and learning.

Now, let's consider a new example, this time using an embedded answer (cloze) question type. The insertion procedures follow the same logic presented previously. Upon selecting the embedded answer option, Moodle again displays the question configuration window, including the "Question text" field. At this stage, it is necessary to apply the specific configurations for this question type, ensuring that the statement is correctly structured (Figure below).

Second example of a moodle question with geogebra applet



The objective of this example is to allow students to calculate the coordinates of the parabola's vertex for each of the presented quadratic functions and subsequently validate their calculations using the GeoGebra window. This way, students can understand the concept across different representation registers for the same mathematical object. It is worth noting that the applet used in this example is the same as in the previous example. This fact reinforces the central point of this article's proposal: the integration between GeoGebra and Moodle significantly expands the possibilities for creating activities. A single GeoGebra applet can be used for various activities, each with different objectives and perspectives.

The procedures demonstrated in this article are just a sample of the countless possibilities for using GeoGebra within Moodle. From this point onward, teachers can explore their creativity and knowledge to develop different applets aimed at teaching various mathematical concepts. Furthermore, it is essential to emphasize that embedding GeoGebra applets into Moodle is not limited solely to quizzes. The same procedure can be applied to various other activities, such as forums, blogs, books, lessons, pages, and assignments. Thus, whether in evaluative or non-evaluative activities, this integration represents significant potential for enriching the teaching and learning of mathematics.

IV. Conclusion

The present article addressed the integration between GeoGebra and Moodle, establishing it as a promising strategy for enhancing the teaching and learning process of Mathematics in the digital environment. By considering GeoGebra as an instructional instrument for developing didactic activities and for conversion between distinct semiotic representation registers, and Moodle as a widely adopted Learning Management System for the distribution and management of online courses, the union of these two educational technologies significantly expands the pedagogical possibilities for educators and students.

This integration allows for the creation of interactive GeoGebra applets directly within the Moodle environment, providing both evaluative and non-evaluative activities with dynamic and visual resources. The examples presented, such as the incorporation of GeoGebra windows into multiple-choice and embedded answer question types, illustrate the potential of this tool to promote the exploration of mathematical concepts in different registers and for students to validate their calculations.

From a theoretical standpoint, Rabardel's Instrumental Approach helps us understand how GeoGebra and Moodle, as artifacts, transform into effective teaching and learning instruments through the process of pedagogical appropriation. Duval's Theory of Semiotic Representation Registers reinforces the importance of coordination between different registers for the construction of mathematical knowledge, an aspect that is favored by GeoGebra's ability to present the same mathematical object under multiple representations.

Therefore, the integration of GeoGebra into Moodle is not limited to a simple addition of functionalities but configures itself as an opportunity for the creation of more dynamic, interactive, and meaningful learning environments for the teaching of Mathematics. By enabling the articulation between different representation registers and promoting the active exploration of mathematical concepts, this technological union contributes to deeper and more engaging learning, meeting the demands of education in the digital era. The flexibility to insert GeoGebra windows into various Moodle activities opens up a vast array of possibilities for teachers to explore their creativity and knowledge in developing innovative pedagogical proposals.

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