Teaching of Related Functions Using *Geogebra* Software: an Experience Report with Students in the First Grade of High School

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Abstract: This research aims to investigate the methodological role of Digital Technologies in the teaching-learning process of Mathematics from the perspective of the National Common Curricular Base (BNCC). In this context, with the aim of making viable a methodological proposal that provides students with a virtual learning environment Classroom, making it favorable to the pleasure of learning Mathematics. Here, the processes triggered in the construction and/or recovery of mathematical concepts and skills from the pedagogical intervention with the *Geogebra* software are investigated. The participants of the research were students in the 1st grade of High School, from a school in the Municipal Network of Denise, state of Mato Grosso. In which they carried out pedagogical intervention activities in the virtual learning environment Classroom, focusing on the use of *Geogebra*. The data were analyzed qualitatively, according to pre-defined analysis units based on French researcher Aline Robert. The results of the process triggered in the construction of mathematical procedures and concepts by the subjects in situations in the Virtual Learning Environment were promising. Based on this investigation, it is expected that a methodological practice will be developed with the use of digital technologies, aiming to correlate mathematical content with the objectives of the BNCC, reaching the level of competences and skills desired by the document.

Key words: related functions; *Geogebra*; Mtehamtics teaching.

I. Introduction

When outlining reflections on the teaching and learning process of Mathematics in the current educational scenario, digital technologies are integrated in a globalized way. For Borba (2012), in the 21st century, when machines enable information and solutions in a reduced time, it is no longer possible for schools to continue to undervalue or disregard technologies in their pedagogical proposals. Above all, this creates challenges for educational institutions for the new generation of students, defined by Prensky (2001) as digital natives.

It is clear that in this dynamism with digital technologies (DTs) as the matrix of the mathematical knowledge production process, schools cannot give up on new technological resources available. Otherwise, they become an obsolete space disconnected from the real needs arising from human intelligence (Borba, 2012).

In this scenario, with the constant transformations in the technological world in which we live, they have influenced the actions and way of life of human beings, pointing out new means, and transforming economic, social, cultural relations and the contemporary educational process, guiding everyone's path towards the mastery and critical appropriation of these new means (Kenski, 2013).

In this sense, many researchers have contributed so that technologies inserted in an educational context could be used in education. Even at a slow pace, digital technologies have been contributing to an innovative scenario. In addition to promoting changes in practices and breaking paradigms, learning based on technical rationality, transforming the process of knowledge production, meaningful for students. Among them, we can highlight: (Borba, 1999; Valente, 1999; Demo, 2011; Borba, Silva, Gandinis, 2014; Souto, 2016; Souto, Borba 2016).

These possibilities, above all, with digital technologies, have provided adaptations for educational actors (teachers, parents, students and managers). Especially if we think of technologies as being "[...] the set of scientific knowledge and principles that apply to the planning, construction and use of equipment in a certain type of activity" (Kenski, 2013, p. 24).

The process of mathematical conceptualization is related to the pedagogical intervention carried out by the researcher supervising the action and not a simple visualization action, but mobilization of mathematical concepts using digital technologies. The pedagogical intervention process triggered in this study was outlined in the methodological procedures based on the BNCC and TDs for Teaching and Learning Mathematics due to the pandemic moment and in compliance with ORDINANCE No. 164/2021/GS/SEDUC/MT. Updates exceptional measures of a temporary nature, to prevent the risks of spreading the coronavirus (COVID-19), within the scope of the State Department of Education. Sole paragraph, the telework regime, described in the caput, will be carried out remotely, during the standard operating hours of the State Department of Education, observing the provisions contained in Decree No. 554, of July 3, 2020.

According to Art. 2, for the purposes of this Ordinance, the following are considered work: II - Telework or remote work: modality in which the public agent performs his/her functional duties outside the premises of his/her organization, through the use of information technologies while the state of public health emergency of international importance resulting from the coronavirus (COVID-19) continues. To this end, the entire process was carried out through the *Classroom* and *WhatsApp* platforms.

In this context, this study investigated the level of understanding and mobilization of the mathematical concept of affine function, according to Robert (1998), by students from the public school system in Denise-MT, with the help of the *Geogebra* software, considering the dictates of the National Common Curricular Base (BNCC).

This work seeks to encourage meaningful learning, articulating technologies such as the *Geogebra* Software and *Classroom* in the construction and systematization of mathematical concepts.

II. Methodological Procedures

The methodology is a qualitative approach research. We justify our choice as follows: "qualitative researchers seek the involvement of participants in data collection and try to establish harmony and credibility with the people in the study" (Lincoln, Guba, 1985; Araújo, Borba, 2012). In real contexts, it allows the researcher to have a vision that converges with their lived experiences with the participants.

III. Participants and research location

The research participants were 28 students in the 1st year of high school (13 to 14 years old) from a public school in Denise-MT. Data production was carried out in the first semester of 2020. The school in question was chosen because its management shows investments in this direction and offers a space that prioritizes innovative activities, allowing the researcher herself to launch research activities. A priori, due to the pandemic situation, Digital Technologies made it possible to monitor and develop the research in a virtual learning environment, the *Classroom*.

This fact arises from the practice of TDs in the classroom in compliance with Ordinance No. 164/2021/GS/SEDUC/MT. It updates exceptional measures of a temporary nature, to prevent the risks of spreading the coronavirus (Covid-19), within the scope of the State Department of Education. According to Art. 2. For the purposes of this Ordinance, work is considered: II - Telework or remote work: modality in which the public agent performs his/her functional duties outside the premises of his/her organization, through the use of information technologies.

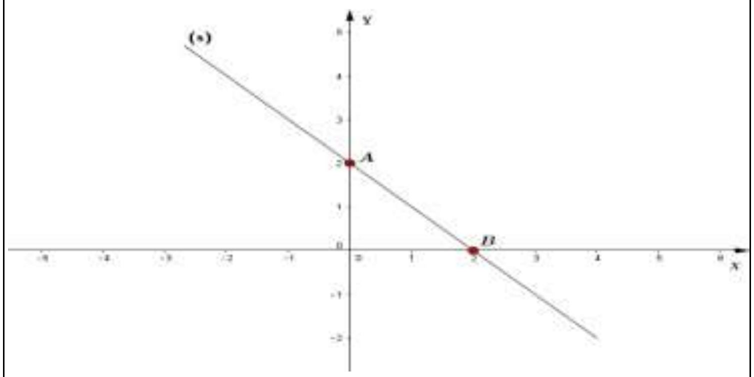
IV. Data production instruments and analysis method

As a data analysis method, we will use the work of researcher Robert (1998) who verified in her research that there are tasks that can require different forms of mobilization of the expected knowledge from students: Technical, Mobilizable and Available. The author understands this classification as an analysis instrument, as it allows to measure the stage of development of students' learning in mathematics, identifying at what level of learning they are. In order to better understand the subject, in our research, we will revisit Robert's (1998) research. We will present the three levels of knowledge functioning proposed by the author.

The students were assessed in this intervention using two instruments: the first consisted of a function task using the *Geogebra* software; the second, a survey that investigated the level of satisfaction regarding the use of Digital Technologies (DT) in teaching mathematics. The investigative procedure was structured in five distinct moments, all carried out with the support of the Google Meet and Google Classroom platforms. The didactic sequence adopted is described below in the table:

Satisfaction Survey with Digital Technologies (DT) in Mathematics Teaching
1 - To what extent did Digital Technologies contribute to your understanding of mathematical content? ( ) Contributed significantly ( ) Contributed moderately ( ) Contributed little ( ) Did not contribute
2 - In your opinion, is the use of *Geogebra* software an important resource for understanding mathematical concepts such as affine functions, straight line equations, and linear systems?
3- How do you evaluate the integration of digital practice in the proposed activities? Describe
4 - Were the classes using *Geogebra* software more motivating than traditional classes?
5 - What positive or negative aspects would you highlight about the use of Digital Technologies in Mathematics teaching? Describe.

Activities developed based on Robert's Theory (1998)		
1º	1) Does the $y = -2x - 3$ pass through the origin of the coordinates?	Task 1 falls within the technical knowledge level, according to Robert (1998), characterized by the direct use of tools — such as theorems or definitions — to solve a task, without the need for conceptual understanding. "

2º	Determine the equation of the line (s) that is represented geometrically in the graph below: 	Task 2, for the author, the mobilizable knowledge level involves more comprehensive tasks than those of the technical level. Despite the teacher's guidance and the notion still being explicit, the resolution requires adaptation of the content, going beyond the simple application of formulas or theorems.
3º	Paulo wants to take a 10 km trip, when arriving at the taxi rank, he asks the taxi drivers how much they charge for a ride. Taxi driver A starts the ride charging 7 reais plus 1.5 reais per kilometer traveled, while taxi driver B starts the ride charging 5 reais plus 2 reais per kilometer traveled. Paulo wants to know, at what point in the trip do the taxi drivers charge the same amount? And what are the coordinates of point A, and still reflecting on the trip, Paulo would like to know, which taxi driver is worth taking this 10km route?	According to Robert (1998), the available level involves tasks that require the student to have autonomy to mobilize prior knowledge, without explicit instructions from the teacher, applying unforeseen strategies to solve the task.

The table presents didactic interventions with Digital Technologies in the teaching of Mathematics, using *Geogebra* and *Classroom* to promote meaningful learning. The actions were organized into five moments, focusing on the exploration of concepts and assessment based on knowledge levels according to Robert (1998).

Intervenções desenvolvidas com Tecnologias Digitais na Matemática			
Moment	**Duration**	**Activities**	**Aim**
1º	4 classes	Initial discussion on the use of Digital Technologies (DT) in Mathematics.	Stimulate reflections on how to solve everyday problems with DT, developing BNCC skills.
2º	4 classes	Use *Geogebra* software to find the angular coefficient of the	Understand the angular and linear coefficients in the function f(x) = ax +

		line.	b.
3º	4 classes	Navigation and exploration of the official *Geogebra* website.	Get to know the virtual environment and locate constructions related to the phenomenon studied.
4º	4 classes	Systematization of concepts: affine function, equation of the line and 2x2 linear system.	Apply knowledge through practical questions (e.g.: FGV-SP question) using *Geogebra* (CAS window).
5º	4 classes	Application of the assessment instrument based on Robert's (1998) levels of knowledge functioning.	Evaluate students at three levels: technical, mobilizable and available, through specific tasks**.**

It is worth mentioning that the tasks were selected according to Robert's (1998) levels of knowledge functioning, which are configured as: technical, mobilizable and available, following some aspects that we consider to be important in the evaluation process. It is worth mentioning that the students solved these activities using pencil and paper, and with the *Geogebra* software, these activities were available to students on the Classroom Platform and also printed in the school environment. It is worth mentioning that the school has been making handout material available since the beginning of the pandemic, and for this reason it was also possible for students who did not have access to the internet to carry out activities on the *Classroom* Platform, but could use the printed material. Thus, tasks that involved abstractions, differentiations and integration in the use of the related function were applied: the tasks addressed the content according to the BNCC skills.

The aim of carrying out the pedagogical intervention was to identify the students according to the level of cognitive development to which they belonged. In order to enable better design of intervention activities with digital technologies in a classroom learning environment, and initial recognition of the subjects and their cognitive possibilities, the following procedures were used in data production: results of tasks at the technical, mobilizable and available levels, and the intervention process and records of activities and protocols were carried out by the researcher herself. Likewise, in the analysis of the data collected regarding the intervention, the researcher had to attend to the following aspects:

- Ask the student to justify their answers and the analyses presented;

- Encourage the student to describe what they think and what they can do to identify procedures and reasoning structures in solving each question;

- Problem-solving procedures involving a complete study of a related function with the *Geogebra* Software;

- Recognition of "errors" and attempts to overcome them;– awareness during use of the *Geogebra* software;

- The elaboration of each activity is structured based on the precepts of Robert (1998), and they were elaborated with strategies and analyses that favor the possibility of identifying the students' levels, systematizing the intrinsic mathematical concepts of affine function, equation of the straight line, and 2x2 linear system, with *Geogebra* software. It is worth mentioning that the demonstration process of these activities was used on the Google Meet platform, as it allowed a discussion on the use of Digital Technologies for learning purposes. By solving this activity using only the *Geogebra* software, it is possible to show students a demonstration to find the angular coefficient.

V. Results and Discussion

These activities were developed based on Robert's theory (1998), which states that students should be able to mobilize knowledge at three levels: technical, mobilizable and available. This study was conducted with the aim of verifying the levels of knowledge functioning that students are at. The research became relevant to determine Robert's levels (1998), enabling the development of skills in activities that required moving from algebraic form to geometric presentation. It is worth noting that the students had previously studied all of these mathematical tools.

The first task implemented is considered to be of a technical level, aiming at the evaluation process to follow the learning process in a more holistic way, going through each level proposed by Robert (1998).

In this task 1, the result will be represented graphically, showing the number of students who answered correctly (yes) and those who answered incorrectly (no). Task 1, shown in Figure 1, according to Robert's (1998) levels of knowledge functioning, is associated with the technical level.

1) Does the equation $y = -2x-3$ pass through the origin of the coordinates?

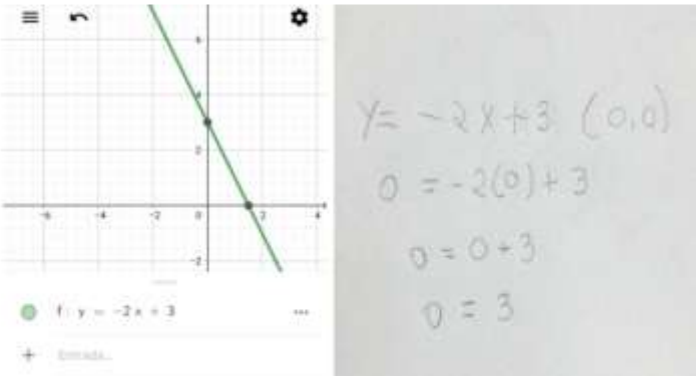
Figure 1 – Task 1, check if the equation of the line passes through the origin.
Source: Authors, 2021

Task 1 is classified as a technical knowledge level of functioning according to Robert (1998), that is, for the author, this level of knowledge represents a mutual relationship to the resolution of a task whose solution is linked to the concrete use of a tool, such as the immediate application of a theorem, a property or definitions, without there being a conceptual understanding of what is being used.

In this task, the student has as one of the possibilities of reaching the solution, substituting the coordinates (0,0) in the equation. Once this is done, the student will verify whether the equality is true/false, otherwise he will be fully convinced that such a line does not pass through the origin. Note that at this point the task requires the mobilization of knowledge that the student has already learned, as in the development of the skill (EF09MA06) Understanding functions as univocal dependence relationships between two variables and their numerical, algebraic and graphical representations and using this concept to analyze situations that involve functional relationships between two variables.

Observe figure 2, where one of the students in the class using the *Geogebra* software, when typing such equation in the input field of the *Geogebra* software, and using the application (Graphic Calculator) a version of the *Geogebra* software for Android and iPhone, immediately obtains the line that represents the equation $y = -2x + 3$, and will notice that such line does not pass through the origin.

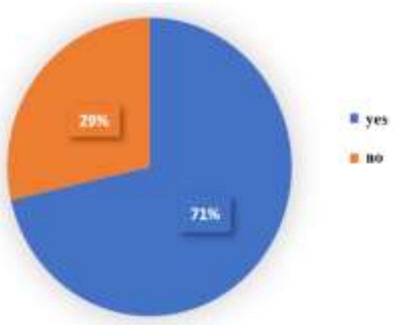
Figure 2 – Technical level task performed by a student in the *Geogebra* software/pencil and paper. Performed by a student making the transition from the algebraic representation to the geometric representation and technical level



Source: Authors (2021).

Graph 1 shows the number of students who are at the technical level according to Robert's theory (1998), obtained in the application of the first task.

Graph 1 – Technical level task according to Robert (1998)



Source: Authors (2021).

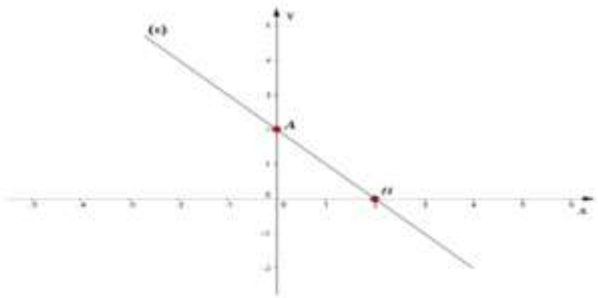
Graph 1 shows the number of students who are at the technical level according to Robert's theory (1998), obtained in the application of the first task. Graph 1 – Technical level task according to Robert (1998)

We can see in graph 1 that during the completion of the first technical level task, it is predominant in the class, as it was possible to observe that only 29% of the students were able to solve the aforementioned task, while 71% of the students demonstrated themselves capable of solving tasks that correspond to the indicated mobilizations, isolated, which explain immediate applications of theorems, properties, definitions, formulas, etc. This is then a trivial, local contextualization, without adaptations. This refers more to the functioning of tools (which include definitions). (Robert, 1998, p. 27).

Task 2, presented in figure 3, according to Robert's (1998) levels of knowledge functioning, is associated with the mobilizable level.

Figure 3 – Task 2 – Geometric representation to algebraic representation and mobilizable level.

Determine the equation of the line (s) that is represented geometrically in the graph below:



Source: Authors 2021

For the author, this level of functioning called mobilizable is designated as tasks that are more comprehensive than those of the technical level, still with indications from the teacher, above all, they go beyond the simple application of property/theorem. At this level, a small adaptation of content is necessary and, although the notion is still explicit, the solution of the task is no longer possible merely by the immediate application of formulas or theorems. The BNCC highlights the skills as being "practical, cognitive and socio-emotional" or as "learning expectation regarding what students should learn" (BRASIL, 2017, p.13).

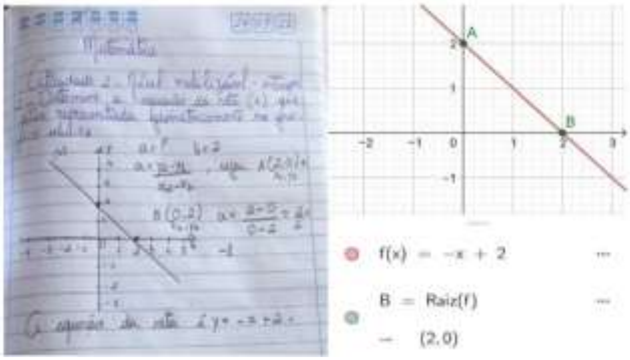
Note that this task aims to use technologies to find a mathematical model, which has important elements to model the problem situation. In this second moment, the skills contemplated are: (EM13MAT302) Construct models using 1st or 2nd degree polynomial functions to solve problems in different contexts, with or without the support of digital technologies. One of the possibilities for the student to reach the solution is to simply identify the factors that will determine its position in the plane, which are the angular and linear coefficients, particular to each function. We know that in any f: R→R, when an addition h to the variable x, passing from x to x + h, there is, in correspondence, an increase f(x + h) – f(x) in the value of the function. Let x and x+h be the number (f(x+h)-f(x))/h, it is called the average rate of variation of the function f in the interval [x, x + h]. Given x, x + h are real numbers, with h ≠ 0, and the affine function f: R → R defined by f(x) = ax + b, its average rate of variation x is given by the number:

$$\frac{f(x+h)-f(x)}{h} = \frac{a(x+h)+b-(ax+b)}{h} = \frac{ax+ah+b-ax-b}{h} = \frac{ah}{h} = a$$

$$\text{Then, } \frac{f(x+h)-f(x)}{h} = a$$

Thus, the average rate of change, in relation to x, of any affine function, defined by f(x) = ax + b, is a. Thus, the student has as one of the possibilities to take any two points belonging to the line (s), and calculate the rate of change of Δy/Δx=a, thus determining the equation of the line, since the linear coefficient is already explicit in the function. See how a student belonging to the class did this activity using pencil and paper and then using the *Geogebra* software version for cell phones.

Figure 4 – Mobilizable level task performed by a student using pencil and paper/*Geogebra* software

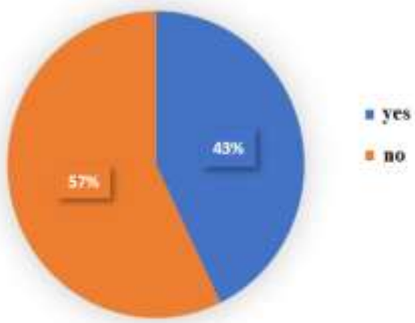


Task 2 – Performed by a student, making the transition from geometric representation to algebraic representation and mobilizable level.
Source: Authors, 2021

We can observe in the resolution of this activity that the student arrived at the solution correctly, it was necessary to mobilize more than one knowledge, we can identify that in the first step the student sought to identify which are the coefficients a and b, clearly the coefficient a is explicit, while the coefficient b is explicit in the geometric representation. Note that the student named any two points. It is worth mentioning that the student mobilized one of his knowledge, since such points belong to line (s), if these points did not belong to said line, it would not be possible to continue in the resolution process. Once this was done, the student calculated the rate of variation between $\Delta y/\Delta x$, finding the angular coefficient a. Note that at this moment the student is juxtaposing her knowledge. Note that the angular coefficient found was a = -1, and the student then describes the equation y = - x + 2.

Graph 2 shows the number of students who are at the mobilizable level in Robert's theory (1998), obtained in the application of the second task.

Graph 2. Mobilizable level task according to Robert (1998)



Source: authors, 2021

We can see in graph 2 that during the completion of the second mobilizable level task, it is noticeable that 43% of the students are able to solve tasks at this level, while 57% are unable to reach the correct solution. For the author, the mobilizable level is characterized by more comprehensive functionings: still indicated, but which go beyond the simple application of a property. This may be, for example, because it is necessary to adapt one's knowledge to apply the appropriate theorem, or change one's point of view or framework with indications. This may also occur because it is necessary to apply the same thing several times in a row or use several different things, in successive stages, or because it is necessary to articulate two pieces of information of different natures.

> In any case, this level had functioning where there is a principle of juxtaposition of knowledge in a given domain, and even of organization, there is not only simple application. What is at stake is explicit, that is, knowledge is said to be mobilizable if, when it is identified, it is well used by the student, even if there is room for adaptation to the particular context. (ROBERT, 1998, P. 27)

Task 3, shown in figure 5, according to Robert's (1998) levels of knowledge functioning, is associated with the available level.

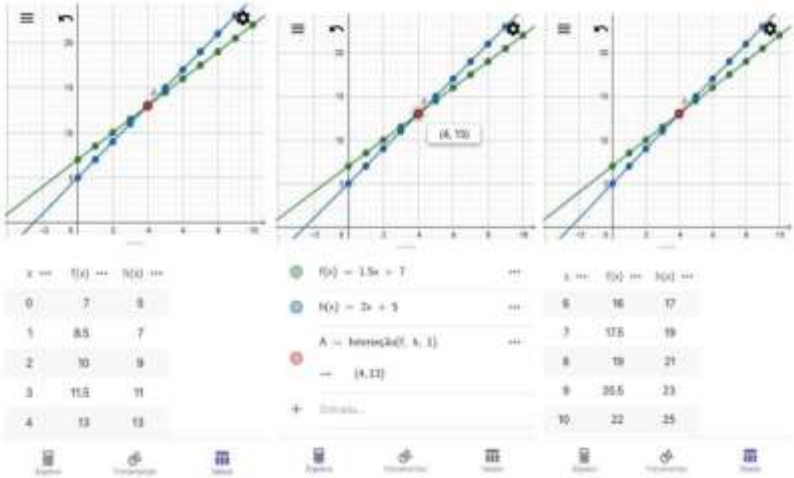
Figure 5 – Task 3 – Solving everyday problems Algebraic representation à Geometric representation à, level Available according to Robert (1998).

Paulo wants to take a 10 km trip. When he arrives at the taxi stand, he asks the taxi drivers how much they charge for a trip. Taxi driver A starts the trip charging R$7 plus R$1.5 per kilometer traveled, while taxi driver B starts the trip charging R$5 plus R$2 per kilometer traveled. Paulo wants to know at what point in the trip do the taxi drivers charge the same amount? And what are the coordinates of point A? And still reflecting on the trip, Paulo would like to know which taxi driver is worth taking this 10 km trip?

Source: Authors 2021

The author presents that at this level, tasks are presented that correspond to the fact of knowing how to solve what is proposed without requiring explicit indications, that is, the student searches in his/her own knowledge what can intervene in the solution. They can apply forms not yet foreseen, in which the student must solve the proposed task without any indication or intervention from the educator. This level requires the mobilization of previous knowledge and choosing what is most convenient for solving the task. We aim to use technologies to find a mathematical model, which has important elements to model the problem situation. In this context, the skill contemplated is: (EM13MAT302) Construct models using 1st or 2nd degree polynomial functions, to solve problems in different contexts, with or without the support of digital technologies. We know that this activity was proposed to be solved using only the *Geogebra* software. Above all, many students know the basic tools of the software, for this reason most of the students solved the activities initially using pencil and paper technologies, while others used the *Geogebra* software at the beginning. See what this student justified in his resolution process using only the DT. It is worth mentioning that this same student found difficulties in solving this task using the *Geogebra* software (Android version) initially, so we are aware that technologies coexist in harmony within the classroom (VILLARREAL; BORBA, 2010), as we can see in the execution of this task [In the Figure 6 – Task 3 from a student – Geometric representation to algebraic representation, Available level according to Robert (1998).

Figure 6 – Solving everyday problem, available level task according to Robert (1998).

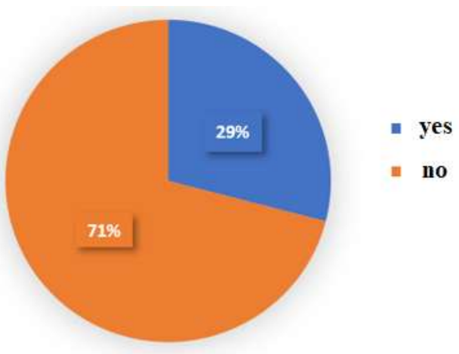


Source: Authors 2021

It is worth mentioning that many students had difficulty solving this Available level task, since this is a task for which students do not receive instructions from the teacher mediating the process, as proposed by Robert (1998). Above all, the students who managed to interpret it correctly completed the entire resolution process. We can see that they found the coordinates at point A. It is clear in the figure that the moment when taxi drivers charge the same amount is after 4 km traveled, and it shows that it is most convenient to make the 10 km trip with taxi driver A. Above all, it is worth mentioning that the entire resolution process was through the *Geogebra* software. Note that for this student, another skill related to the 1st, 2nd and 3rd years of high school is developed, which says: (EM13MAT 301) Solve and elaborate everyday problems, mathematics and other areas of knowledge, which involve simultaneous linear equations using algebraic and graphical techniques, with or without technology.

Within this context, we can see how important it is for students to be involved in this process of developing tasks according to their respective level. We can see that most of the students solved technical level activities. As we moved to the mobilizable level, this number of students decreased. When we reached the available level, only 29% were able to reach the solution correctly. It is clear that these students developed the skills that were contained in the activity. This data was analyzed in the reflections on how to intervene.

Graph 3 – task level available according to Robert (1988)



Source: Authors 2021

We can see in graph 3 that 71% of students are not at the available level, only 29% of students. The available level is classified by the fact of knowing how to solve what is proposed without indications, of searching in their own knowledge what can intervene in the solution. For example, being able to provide counterexamples, find or invent, change frameworks without suggestion-relate and apply unforeseen methods are behaviors that are expected at this level.

This level of functioning is linked to an important connection with the knowledge of situations with different references, which the teacher knows he knows, and can serve as an environment for experimentation, due to the fact that he has references, questions, and an organization. This can include the fact that the teacher, when preparing his classes, does so in a way that only presents problem situations or proposes activities constructed through didactic sequences that have already been analyzed and with objectives set to be achieved (Robert, 1998, p. 27).

Final Considerations

The study of the concept of affine function with students actively participating in the teaching and learning process made it possible to fully explore the potential of the *Geogebra* software and, together with the Classroom learning environment, seek understanding of the concept under discussion. It is worth noting that the dynamics of students browsing the Official *Geogebra* website contributed to their ability to manipulate activities that were related to the specific concept of affine function. Within this context, Gomes and Padovani (2005) classify Digital Technologies as an interactive computational system, designed to contribute to the learning of specific content.

This research clearly demonstrated the need to use Digital Technologies in Basic Education Schools. It is worth mentioning that many students are at the technical level according to Robert (1998), even with intense interactions in sincere and asynchronous moments. Above all, we verified the need to stimulate the development of logical mathematical reasoning in these students, since it contributes to desirable mathematical knowledge, as suggested by Robert (1998) at the available level. According to Souto and Borba (2016), they show that Digital Technologies in teaching involve students in a learning process, since for the authors, digital technologies are a reality experienced in the student's daily life.

To this end, the use of DTs in teaching Mathematics has proven to be essential, since the transformations in the production of knowledge resulting from the technological advances that we are currently experiencing have proven to be a challenge, especially when other technologies such as educational software are associated with this context (Souto; Borba, 2013). According to Borba and Villarreal (2005), a new intelligence technology results in a new collective that produces knowledge that, in turn, is qualitatively different from the knowledge produced by other collectives.

Returning to the research question: What is the level of understanding and mobilization of the mathematical concept of affine function, according to Robert (1998), by students from the public school system in Denise-MT, with the help of digital technologies considering the dictates of the BNCC? We can observe that DTs played a fundamental role in the production of mathematical knowledge, specifically those that were directed to the affine function, achieving important skills proposed by the BNCC. However, we understand that an activity system developed in an online learning environment generates challenges and is conditioned to deal with social and cultural factors, among others. To this end, from a theoretical point of view, we seek to understand the mobilization of mathematical concepts mediated by DTs, that is, we base the analyses on the theory of tools for analyzing mathematical content to be taught (1998).

Data analysis suggests that students perform tasks with different levels of knowledge mobilization, since according to Robert (1998), students must be able to mobilize knowledge at three levels: technical, mobilizable and available. We consider it appropriate to emphasize that in this research, most students are at the technical level, which leads us to reflect on continuing with investigative practices that enable us to contribute to satisfactory teaching and learning.

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