Chapter 13
Integration of GeoGebra in Teaching and Learning of Mathematics in the Niger Republic Classrooms

Abdoul Massalabi Nouhou

Introduction

Information and communication technologies (ICT) are an opportunity in all activity sectors because they make many services and daily activities easier. It is undeniable that the education sector is not an exception. Therefore, the higher secondary education system should promptly adopt new ICT tools and know-how to harness their power to train learners (Grinshkun & Osipovskaya, 2020, p. 1). The Mathematics Learning Process through ICT can be a response to the needs of the fourth Industrial Revolution (4IR), where technological progress aligns with human needs, more specifically by improving students' skills to meet the changing demands of 4IR. The integration of new technologies in teaching and learning mathematics can help children in African countries prepare for lifelong learning and the ability to predict the upcoming changes.

Literature Review

The literature review of this research was built from three aspects. The first aspect is the Fourth Industrial Revolution (4IR). According to Schwab (2017), the 4IR is a technological revolution that has altered our very being in terms of how we live, work and relate to one another. The scope and complexity of this transformation will not resemble anything that humanity has experienced during the previous industrial revolutions. The 4IR is characterised by the fusion of the digital worlds and disciplines (biology, mathematics, physics …), nonlinearity, and the re-emergence of digital into material and physical domains. The key to the 4IR is that

A. M. Nouhou (✉)
Abdou Moumouni University, Niamey, Niger

B. Chirinda et al. (eds.), *Mathematics Education in Africa*,
https://doi.org/10.1007/978-3-031-13927-7_13

today's youth will no longer start a career path or grow in one role; roles will change regularly (Naidoo & Singh-Pillay, 2020, p. 2). Equipping African citizens with the skills needed in an evolving job market is necessary. They have to be prepared for lifelong learning and have the ability to predict change. In education, teacher training programs should improve the educational processes and outcomes of the educational system. It must be constantly reformed in the light of adjusting to the new technological changes and must be the object of continuous evaluation. Therefore, we can retain that a new form of mathematics education is emerging from the fourth industrial revolution.

The second aspect is the transformation of the mathematical learning process through new technologies (Grinshkun & Osipovskaya, 2020, p. 3). GeoGebra is a software created by Markus Hohenwarter to improve mathematics learning through ICT. The acronym GeoGebra derives from two words: ***Geo*** *of Geometry and* ***Gebra*** *of Algebra.* GeoGebra is an interactive geometry, algebra, statistics and calculus application for learning and teaching mathematics and sciences from primary school to the university. This dynamic mathematics software is free to access and can be used in several languages, such as French. It is available on multiple platforms and websites. GeoGebra is being used in other educational disciplines.

GeoGebra can be installed and used for learning about computers, tablets and smartphones. GeoGebra is software that allows an individual to work on multiple representations of a function object. It can be used as an environment for actively exploring the function of a mathematical object (Freiman et al., 2009, p. 39). The entry line is used to write algebraic and symbolic expressions for the function object. The algebraic window displays the algebraic, the numerical or the formal writings. The dynamic working window is used to display the graphic representation of the function (the curve and the graph). The formal calculation window allows you to enter symbolic expressions of the function and perform the usual calculations of the functional analysis (solving an equation or inequation, calculating the limits, calculating the derivative, calculating the integral, etc.). The spreadsheet window allows you to enter numbers, coordinates, functions or commands and establish a correspondence table (x; y). GeoGebra software can offer higher secondary students the possibility of mobilising several registers of semiotic representations of the mathematical function during the learning process. It can be learned from this literature review that the emergence of ICT tools such as GeoGebra can improve the process of mathematical learning in relation to the requirements of the 4IR in Africa.

The third aspect is the approach to teaching and learning mathematics concepts, such as the concept of mathematical functions in higher secondary school. The mathematical functions are tools of problem solving, and this acquires greater visibility by studying some of its properties, distinguishing between algebraic, numerical, geometric and analytical registers for the concept of mathematical functions. Each register of representation does not explain the same aspects of the concept of a function, and the absence of an interaction of the frames makes students experience difficulties coordinating the different contexts. Therefore, it is essential for the learning of mathematical functions to be able to mobilise several registers of semiotic representations (Duval, 2002, p. 83) and to insist particularly on the interaction between the registers to validate the mathematical properties of this concept (Bloch, 2003, p. 26). Dynamic mathematical software offers multiple representations of mathematical function and its visualisation, a potential that can contribute to the learning of higher secondary school students (Minh, 2012).

From this literature review, we examine the key challenges of mathematics learning to enable higher secondary school students to meet the demands of 4IR in Niger. We formulated the following research question: ***How does the integration of GeoGebra in the teaching and learning of mathematics in Niger enable students to accommodate the requirements of the 4IR****?*

Theoretical Framework

The theoretical framework of this research was built from two theories. The first is the theory of semiotic registers of representation (Duval, 2006). This approach provides a framework for studying the activity of mathematics as the activities of the students around the treatments of the registers of representation and conversions. Duval (1993) internalises the distinction between a mathematical (conceptual) object and its representation. It introduces the notions of semiosis and noesis to designate the apprehension, or production, of a semiotic representation and the conceptual apprehension of an object, respectively. He says that «noesis is inseparable from semiosis» to promote learning. The semiotic aspects of the mathematical activity propose an analysis of the activities of the pupils around the treatments of the registers of representation and conversion. According to Coppé et al. (2007), there are six main registers in teaching and learning numerical functions: the register of the natural language, the algebraic register of formulas, the graphic register of curves, the numerical register of table values, and the graphic register of variation tables and the symbolic register. This theoretical framework enables us to analyse the student's activities in solving problems with Geogebra tools (Jacinto & Carreira, 2017, p. 1118) and understand the strategies of treatment registration and conversions of the registers used during this process.

The second construct of the theoretical framework is the theory of semiotic mediation (Bussi & Mariotti, 2008). This approach provides a framework for studying the activity in mathematics as a mediated activity. The mediating potential of an artefact is related to the accomplishment of mathematical tasks through this artefact (Mariotti & Maracci, 2010). The Geogebra software can allow students to work simultaneously on the multiple representations of the function. For example, writing an algebraic expression of a function in the input line (register of algebraic writing), the algebraic expression of this function immediately appears on the algebra window (register of algebraic symbolic expression), and its representative curve is plotted in the dynamic worksheet (graphic register). We will analyse the mediation of the GeoGebra tools in the process of solving mathematical functions.

Methodology

The quasi-experimental approach was retained to examine the key challenges of mathematical learning through GeoGebra among higher secondary school students. It was built from five (5) points: the field of our research, the participants, the observation tools, analysis of secondary higher school mathematics programs, and the data processing tools collected.

The Field of Our Research

In our research field, this public higher secondary school welcomes students of all socioeconomic classes due to its position in the Agadez region (Niger Republic). The school has 627 students of the three levels of higher secondary school, divided into 15 classes, in 2017–2018, the year in which our experiment began.

Our research approach is quasi-experimental with a non-equivalent control group. That is to say; our non-probability sample is composed of experimental and control mathematics classes.

The Participants

The participants of this research are 65 students. Two Mathematics classes were randomly chosen, with the normal age of the students ranging from 17 to 18. The experimental group of 34 students of class mastered the features of GeoGebra related to mathematical functions (SC2), while 31 students of class 1 did not master them (SC1).

The Observation Tools

The observation tools have been developed and validated during the pre-experimental phase. Two (2) teachers checked the consistency of the content of the test scores before it was administered to the students of the experiment. At the end of the experiment, five (5) copies were drawn randomly from the sets of copies and photocopied in triple. The two teachers and the researcher corrected the five copies based on the initial correction grid. The comparison of the results gave a value of 0.99 for the Alpha of Cronbach (Less than 0.70). This confirms the internal consistency of the instrument for measuring the test scores.

Analyses were conducted at two levels. The first level of analysis examined the learning gains. The unit of analysis was *the cognitive gains in learning mathematical functions.*

The second level of analysis examines the mathematical tasks of the register of the semiotic representation of the mathematical functions in the base of the current mathematics syllabus in higher secondary school (MES, 2016). The unit of analysis was *an occurrence of each of the strategies of treatments of the register of the semiotics representation of the mathematical function, conversions of the registers and obstacles* identified related to GeoGebra tools.

Analysis of Higher Secondary School Mathematics Curriculum

The analysis of the higher secondary school mathematics curriculum will allow us to clarify the treatments of semiotic representation registers of mathematical functions (Table 13.1) and Conversions of registers (Table 13.2), which will be approached during the teaching and the learning process, and the mathematics learning with GeoGebra.

Learning Approach of the Concept of Functions in Higher Secondary School

Before the experimentations, the two teachers prepared two mathematics sessions of mathematics lessons according to the current ASEI / PDSI approach[1]implemented by the SMASSE[2] program in Niger, since October 25, 2006. In preparing for these lessons, they developed two mathematics lesson sheets. Each mathematical lesson sheet describes the learning scenario representing the a priori description of the progress of the learning situation of the numerical function. The aim was to describe all activities for the appropriation of a given mathematical concept by specifying, among other things, the role of the teacher and that of the learners, the activities to achieve, the resources available for achieving the learning objectives, the didactic tools and the forms of mediation necessary for the implementation of teaching and learning activities. The scenario follows the course of the pedagogical progression; therefore, the sequence of these steps only makes sense if the teacher achieves the set goals before moving on.

[1] https://www.jica.go.jp/niger/french/activities/activity01.html

[2] SMASSE = Strengthening of Mathematics And Sciences in Secondary Education

Table 13.1 Treatments of semiotic representation registers of mathematical functions

Semiotic representation registers	Code	Treatments of semiotic representation registers
The algebraic register of formulas	Ra	Determine the definition or study set of the mathematical function (Ta1) Calculate the image, the antecedent of a number (Ta2) Calculate algebraic equations (Ta3) Algebraic calculation of inequalities (Ta4) Calculate the limit of a function (Ta5) Deduce the expression of the equation or the inequality (Ta6) Determine the algorithmic expression of a function (Ta7)
The intrinsic symbolic register	Rs	Write $f < g$ (Ts1) Write $f = g$ (Ts2) Write $\lim_{x_0} f$ (Ts3) Write the sign $(+\infty, 0ou - \infty)$ (Ts4) Determine $C_f \cap C_g = \{A\}$ (Ts5) Determine $C_f \cap (xx')$ (Ts6)
The natural language register	Rl	Define the relative position of two mathematical functions (Tl1) Define the limit of a mathematical function at a point (Tl2) Verbal or written interpretation (Tl3) Interpretation by a mathematical language (Tl4) Interpretation of the relative position of the two curves (Tl5)
The graph register of curves	Rg	Place a point (Rg1) Draw the curve of a function (Tg2) Read the image graphically, the antecedent of a number (Tg3) Graphically read a function over a given interval (Tg4) Find the solutions of an equation or an inequality graphically (Tg5) Find the relative position of a curve with respect to a straight line with respect to another curve (Tg6) Graphically read the sign of a function (Tg7) Graphically read the limit of a function (Tg8) Graphic interpretation (Tg9) Graphically read the coordinates of a point (Tg10) Use zoom for graphical visualisation (T11)
The numeric register of tables of values	Rn	Read coordinates (Tn1) Read the trend of numerical values (Tn2) Determining the coordinates of a point (Tn3) Complete table of values (Tn4) Determine the numerical value corresponding to the solution of an equation (Tn5) Determine the interval for numerical values corresponding to the solution of an inequality (Tn5)
The graphic register of variation tables	Rv	Calculation of the comparison from the trends of the curves of two of the functions, f and g (Tv1) Draw up the table of the signs of the difference between f and g (Tv2)

Table 13.2 Conversions of semiotic representation of registers of mathematical functions

Semiotic representation registers	Direction	Conversions of semiotic representation registers
The algebraic register of formulas (Ra) and the graphic register of curves (Rg)	$Ra \to Rg$	From an algebraic expression of a mathematical function, draw a curve (Cag)
	$Rg \to Ra$	Find the algebraic expression of a mathematical function whose curve is known (Cga)
The algebraic register of formulas (Ra) and the numerical register of tables of values (Rn)	$Ra \to Rn$	From an algebraic expression of a mathematical function, establish a spreadsheet of values (Can)
	$Rn \to Ra$	From a table of values, establish an algebraic expression of a mathematical function (references functions) (Cna)
The algebraic register of formulas (Ra) and the register of variation tables (Rv)	$Ra \to Rv$	From an algebraic expression of a mathematical function, establish a variations table (Cav)
	$Rv \to Ra$	From a variations table, establish an algebraic expression of a mathematical function (references functions) (Cva)
The numerical register of the table of values (Rn) and the graphic register of curves (Rg)	$Rn \to Rg$	Plot a curve of a mathematical function from the table of values (Cng)
	$Rg \to Rn$	Find the table of values of a mathematical function whose curve is known (Cgn)
The numerical register of the tables of values (Rn) and the register of the variation tables (Rv)	$Rn \to Rv$	From the table of values of a mathematical function, establish a table of variations (Cnv)
	$Rv \to Rn$	From the table of variations of a mathematical function, establish a table of values (Cvn)
The graph register of curves (Rg) and the register of variation tables (Rv)	$Rg \to Rv$	From a curve of a mathematical function, establish a table of variations (Cgv)
	$Rv \to Rg$	Find a curve of a mathematical function whose table of variations is known (Cvg)

Presentation of the Problems on the Mathematical Functions and a Priori Analysis

Problems 1 and 2 were chosen by the mathematics teachers during the mathematics teaching unit (MTU) meeting according to the mathematics program in Niger (see appendix). This approach is part of choosing an ordinary math class experimentation. The teachers had chosen problem 1 to introduce the mathematical notion of comparing two mathematical functions. According to the mathematics program, the objective was “to compare two functions (algebraically and graphically)”. Problem 2 was proposed to the students by the teachers during the introduction of the mathematical notion of function limits at a point x_0 (see appendix). According to the program, the objective was to “establish the behavior of the reference functions”.

As for the resolution of problem 1, the students are called upon to work on the semiotic representations of functions in the GeoGebra environment. To answer the question (a), they can mobilise the algebraic expressions of the functions f and g (Ra) to graphically represent the curves of these two functions (Rg). This process involves converting the algebraic expression to a graphical framework (Cag). Students can use the input tool to input algebraic formulas, and GeoGebra‘s graph tool will allow students to plot representative curves for functions f and g. To answer question (b), that is to say, complete the correspondence table, the pupils can mobilise the graphic representations of the curves of the functions f and g of the curves (Rg) from the graph tool to place the coordinates of the points (x; f(x)) and (x; g(x)) then read the coordinates of each point and write the numerical value of the image of numbers in the table. It is in this process of passing from the graphic frame to the numerical expression of the coordinates (Cgn). Students can use the point tool to place the different points and read the ordinates. Students can also use the input tool to input the algebraic expressions of each function (Ra) for the values given in the table of values in the GeoGebra environment and then use the spreadsheet tool to calculate coordinates (x;f(x)) and (x;g(x)) (Rn). To answer question (c), students can use table of values (Rn) to conjecture that the functions f(x) = g(x) (Ra). This resolution process allows the pupils to pass from the numerical expression to the algebraic writing (Cna). Students can identify from the correspondence table the values of x having the same image by f and by g and make the conjecture algebraically. To answer question (d), i.e. to make a graphic comparison between two functions over a given interval, the pupils can mobilise trends of the curves (Rv) to interpret by sentences the relative positions of the curves of these two functions (Rl), then compare f(x) and g(x) (Ra) on a given interval algebraically, finally to be able to interpret it symbolically (Rs). The process requires a passage from the variation of curves over a given interval to natural language (Cvl), from natural language to algebraic writing (Cla), and from algebraic writing to symbolic expression (Cas). Students can use the graph tool to visualise and read the relative positions of the two curves over a given interval (Rg) and interpret this algebraically (Ra) (Cga). Students can use the zoom tool on the curve of the two functions (Rg) to make it easier to read the two curves on the interval (Ra). To answer question (e), students can mobilise the graphical representations of f and g (Rg) to read the coordinates of these points (Rn). It is in this process of the passage of the point of the intersections of the two curves to obtain the numerical coordinates (Cgn). Students can use the intersection tool to determine the intersection points of these two curves and read the coordinates of the intersection points with respect to the axes. They can use the zoom tool on the curves of the two functions to enlarge the image (Rg) and get approximations of the numerical values (Rn) (Cgn).

As for the resolution of problem 2, the students are asked to work on the semiotic representations of functions in the GeoGebra environment. To answer question 1., i.e. to complete the table of values, the pupils can mobilise the algebraic expressions of each of the reference functions (Ra) to represent these functions in the GeoGebra environment and then complete the table of values (Rn). It is explicitly a process of converting the algebraic expression to a numerical expression (Can). Students can use the input tool to input the algebraic expressions for each datum function (Ra) into the GeoGebra environment and then use the spreadsheet tool to calculate coordinates numerically (Rn) (Can). They can also use the graph and point tools to place the corresponding points (Rg) and then read and write the numeric value of the image in the table (Rn). This process will therefore require students to do a double conversion (Cag) then (Cgn). Students can also calculate the coordinates from the algebra tool by calculating the images of the given antecedents (Ra) and then read and write in the correspondence table (Rn). To answer question 2a, students can use the table of values (Rn) to read the trend of the numerical values of x^2 as a function of that of x to conjecture that "when x becomes infinitely large, x^2 becomes infinitely large" (Rl). It is a process that consists of the transition from digital to natural language (Cnl). The students can visualise the trend of the square function by visualising its representative curve (Rg) using the graph tool and then make a conjecture on the behaviour of the function in the neighbourhood of x (Rl). They can mobilise the computer algebra tool to calculate algebraically (Ra) and finally validate their conjuncture. To answer question 2b, students are asked to rely on the information stated, from the expression "when x becomes indefinitely large" to a suitable mathematical language expression "x tends to $+\infty$" (Rl) for deducing the appropriate "$+\infty$" sign (Rs). This is a shift from proper language to symbolic expression (Cls). To answer question 3), students can use the terms "infinitely large" or "infinitely small" to pass a more suitable expression "$+\infty$" or "$-\infty$" and deduce the behaviour of each of the reference functions in terms of "$+\infty$", "$-\infty$" or 0. This is a change from a formal language to a symbolic expression (Cls).

Findings and Discussion

Regarding the point of finding and discussion, we can retain two main results: *the cognitive gains scores for students in learning the mathematical functions* and *the strategy of treatments, conversions of register of semiotics representation of the mathematical function.*

The Cognitive Gains Scores for Students in Learning Mathematical Functions

Figure 13.1 shows that the mean scores of the pretest for students in the two classes of mathematics classes are less than the average scale of 100. The difference in the mean score of the two groups is not significant. The result shows that the students of these classes have a lower level. The graphic also shows that the means scores of the posttest are higher than the average of 100. The difference in the mean score of the two classes is significant.

Fig. 13.1 Means scores

Table 13.3 Comparison of the means at the pretests and posttests of the two class groups

Students of class	Number of students	Pretest			Posttest		
		Means	Standard deviation	Coefficient of Variation	Means	Standard deviation	Coefficient of Variation
SC1	31	32	10.80	0.34	57.26	20.62	0.44
SC2	34	36.35	15.81	0.43	76.21	16.76	0.34

Table 13.3 above shows an analysis of the level of knowledge at the start of the pupils. For SC1, the pretest mean is 32, the standard deviation is 10.80, and the coefficient of variation is 0.34. For SC2, the pretest mean is 36.35, the standard deviation 15.81, and the coefficient of variation 0.43. Kruskal Wallis' chi-square statistical test indicated that the difference in mean scores between the two groups is insignificant ($p > 0.5$). This result indicates that the pupils of these three classes are globally at the same level of knowledge before the teachers' interventions. However, the averages obtained by his students are below 50, a value for which it is considered that the group of students has globally reached the average threshold out of 100 in terms of knowledge of the mathematical concept of function. In the beginning, the participant students had a low level of knowledge of numerical functions with real variables.

Secondly, an analysis of the level of knowledge after the pedagogical intervention (see Fig. 13.2). For SC1, the pretest mean is 57.26, the standard deviation is 20.62, and the coefficient of variation is 0.44. For SC2, the pretest mean is 76.21, the standard deviation is 16.76, and the coefficient of variation is 0.34. Kruskal Wallis' chi-square statistical test indicated that the difference in mean scores between the two groups is significant ($p < 0.5$). This result indicates a statistically significant difference in knowledge acquisition between the students of these three classes after the teachers' interventions in favour of SC2. This result reveals that

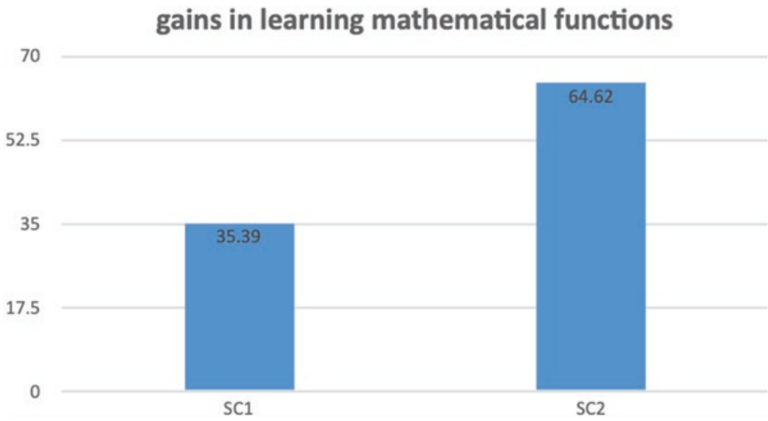

Fig. 13.2 Gains in learning mathematical functions

Table 13.4 Correlation between pretest and relative gain for the three-class groups

Students of class	Number of students	Correlation (r)	P-value
SC1	31	−0.49	0.010
SC2	34	0.098	0.581

using Geogebra enabled SC2 students to perform significantly on scores compared to the other two groups. It also appears that the averages obtained by its two groups are above 50, a value for which it is considered that the group of students has globally reached the average threshold out of 100 in terms of the acquisition of knowledge of the mathematical concept of function during learning. Students who have mobilised the potential of the software have reached three-quarters (3/4) of the maximum threshold of knowledge required according to the learning objectives of the mathematical functions.

Figure 13.2 shows a gain of 35.39 for the students of SC1 and 64.62 for the students of SC2. These results show that the students of SC2 made a 64.62% gain in learning mathematical functions while the students of SC1 made a 35.39% gain. This means that students who master the features of GeoGebra have significantly progressed in learning mathematical functions compared to those who do not master the features of GeoGebra. This corroborated with the research thesis of Vasquez (2015), who estimated that if students learned how to use GeoGebra before learning mathematics with the software, it would enhance the mathematics learning process through ICT. This illustrates the need to accommodate requirements for the 4IR in mathematics learning through ICT.

Table 13.4 shows the analysis of the correlations between pretest and relative gain. The results are negative and significant in SC1 ($r = -0.490$ and $p = 0.010 < 0.05$) while it is only positive and no significant in SC2 ($r = 0.098$ and $p = 0.581 > 0.05$). These results indicate that learning the functions made it possible for the weakest pupils at the start in SC1, while in SC2, all the pupils progressed in learning the functions whatever their starting level.

The observations of the students during the learning of mathematical functions show that students of SC1 had difficulties writing expressions for mathematical functions. In contrast, the students of SC 2 could overcome these obstacles related to the algebraic writing adapted to the tool seized from GeoGebra.

Writing square function on GeoGebra tools requires converting $f(x) = x^2$ into the expression $f(x) = x$ ^ 2 (caret) (Fig. 13.3).

For writing the square root function requires to convert $f(x) = \sqrt{x}$ into to the expression f(x) = sqrt (x) (Fig. 13.4).

These two expressions of the same mathematical function have the same denotation, but their algebraic representations are different. The first representation is an algebraic symbolic expression, while the second is a computerised algebraic expression. These algebraic algorithmic expressions of the mathematical function adapted

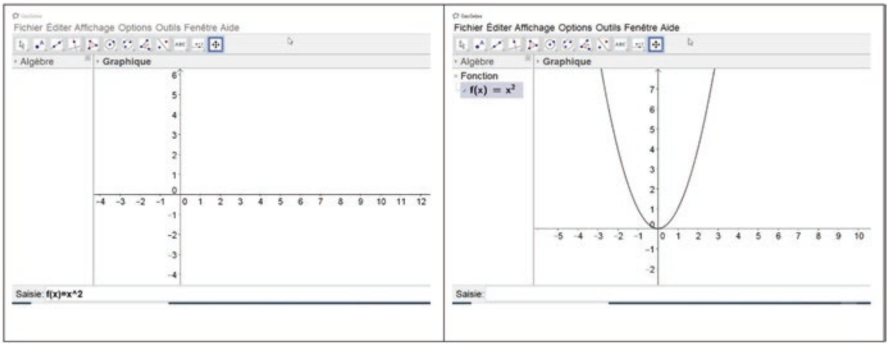

Fig. 13.3 Square function written on GeoGebra tools

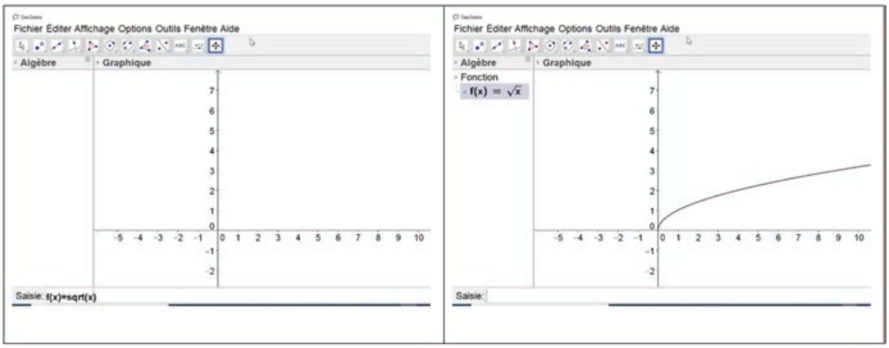

Fig. 13.4 Square root function written on GeoGebra tools

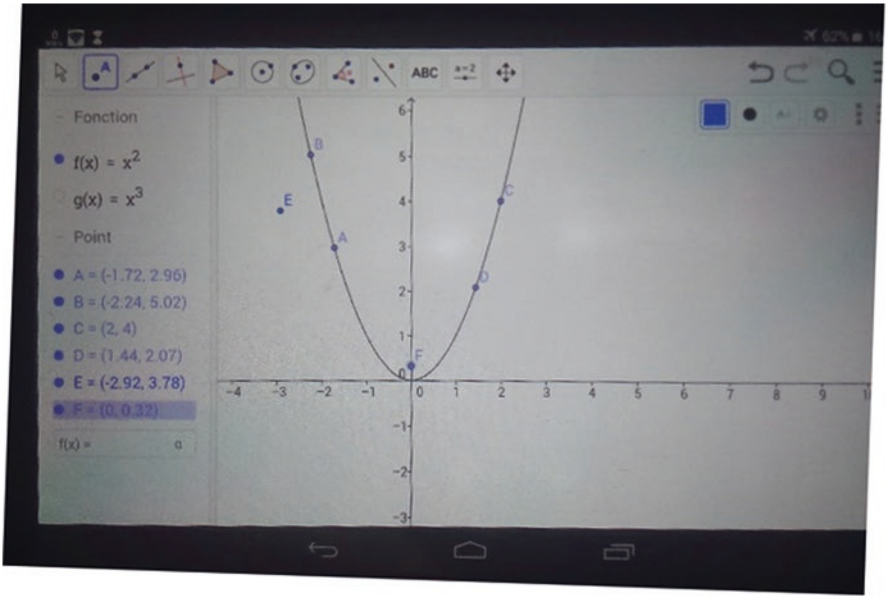

Fig. 13.5 Wrong use of the algebraic tool by students

to GeoGebra are external to the classical semiotic representation system of mathematical functions at a higher secondary level. These expressions are unfamiliar to students (Artigue, 2002). must learn all mathematical function expressions before the process of solving problems; otherwise, GeoGebra indicates that the expression is inappropriate.

The findings show that the students of SC1 encountered difficulties in making conversions of the algebraic register of formula into the numerical register of table values using the GeoGebra tools (Fig. 13.5). The students of SC2 also encountered the same difficulties, but they could overcome them personally by asking for help from the teacher. For example, to complete the table value of the algebraic expression of the mathematical function. The Students of SC1 used the algebraic tool of GeoGebra despite the difficulties instead of the calculus tool. On the other hand, those in SC2 quickly realised that this tool was inappropriate for this task. They, therefore, adapted the algebraic tool. This result shows that even among students who have mastered GeoGebra features, certain manipulations of dynamic software remain difficult (ibid, p. 252) without anticipating these obstacles or the teacher's intervention. These results show that integrating GeoGebra in teaching and learning mathematics will require greater student efforts. This show that mastering the features of GeoGebra in relation to the mathematics concepts can enhance the mathematical learning process through ICT and enable students to accommodate requirements for the 4IR.

Conclusion

The Fourth Industrial Revolution led to new technologies for teaching and learning mathematics. Mathematics learning processes must be constantly reformed in the light of adjusting to the new technological changes and must be the object of continuous evaluation.

The results of this research reveal that it is important for students to master the features of GeoGebra to make significant progress in learning digital functions in high school using this dynamic software. The results also reveal that introducing an algebraic algorithmic expression of the function adapted to GeoGebra makes the activity on numerical functions more complex (Artigue, 2002). The role of the teacher as a guide is necessary for particular semiotic tasks that are not taken into account by classical semiotic analyses.

The use of Geogebra in learning mathematical functions can be evident (Jacinto & Carreira, 2017). It offers the students multiple representations of semiotics registers and their visualisations, a potential that can contribute to the learning (Minh, 2012). This research suggests that the teacher should think, before any intervention, about structuring the learning environment of mathematical functions using GeoGebra to allow students to use treatment and conversations of semiotic registers strategies.

Our findings reveal that mastering the features of GeoGebra in relation to the mathematical notions plays an important role in the mathematical learning process through this ICT. It is one of the key challenges of mathematical learning through ICT to enable higher secondary school students to accommodate the requirements of 4IR in the Niger Republic.

Appendix

Problème 1

On considère les fonctions f et g définies par: $f(x) = x^2$ et $g(x) = x^3$. C_f et C_g sont les courbes représentatives de f et g.

(a) Représenter graphiquement les fonctions f et g à l'aide du logiciel GeoGebra.
(b) Compléter à l'aide de GeoGebra le tableau des valeurs suivant.

x	−3	−2	−1	0	1	2	3
$f(x)$							
$g(x)$							

(c) Identifier dans le tableau les points où f et g sont égaux?

(d) Comparer graphiquement les fonctions f et g sur l'intervalle $[-3; 3]$.
(e) Déterminer les points d'intersection de C_f et C_g avec l'axes des abscisses.

Problème 2

1. Compléter le tableau ci – dessous. On donnera les résultats sous forme d'une puissance de 10.

X	-1000	-100	-10		10	100	1000
x^2							
x^3							
$\sqrt{x}$							
$\frac{1}{x}$							
$\frac{1}{x^2}$							

2. (a) Que devient x^2 lorsque x devient indéfiniment grand?
   (b) Lorsque x devient « indéfiniment grand », on convient de dire que x tend vers $+\infty$. Remplacer alors les pointillés par $+\infty$.

$$\text{Lors}\,\textit{que}\,\text{x tend vers}\ldots;x^2\text{ tend vers}\ldots\ldots$$

3. Remplacer alors les pointillés par $+\infty$, $-\infty$ ou 0.
   (a) Lors que x tend vers $+\infty$; x^3 tend vers ……
   (b) Lors que x tend vers $+\infty$; $\sqrt{x}$ tend vers ……
   (c) Lors que x tend vers $+\infty$; $\frac{1}{x}$ tend vers ……
   (d) Lors que x tend vers $+\infty$; $\frac{1}{x^2}$ tend vers ……
   (e) Lors que x tend vers $-\infty$; x^2 tend vers ……
   (f) Lors que x tend vers $-\infty$; x^3 tend vers ……
   (g) Lors que x tend vers $-\infty$; $\frac{1}{x}$ tend vers ……
   (h) Lors que x tend vers $-\infty$; $\frac{1}{x^2}$ tend vers …..

References

Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work. *International Journal of Computers for Mathematical Learning, 7*(3), 245.

Bloch, I. (2003). Teaching functions in a graphic milieu: What forms of knowledge enable students to conjecture and prove? *Educational Studies in Mathematics, 52*(1), 3–28.

Bussi, M. B., & Mariotti, M. A. (2008). Semiotic mediation in the mathematics classroom: Artifacts and signs after a Vygotskian perspective. In *Handbook of international research in mathematics education* (p. 746). Routledge.

Coppé, S., Dorier, J.-L., & Yavuz, I. (2007). De l'usage des tableaux de valeurs et des tableaux de variations dans l'enseignement de la notion de fonction en France en seconde. *Recherches en didactique des mathématiques, 27*(2), 151–186.

Duval, R. (1993). Registres de représentation sémiotique et fonctionnement cognitif de la pensée. *Annales de didactique et de sciences cognitives, 5*, 37–65.

Duval, R. (2002). Comment décrire et analyser l'activité mathématique? Cadres et registres. *Actes de la journée en hommage à Régine Douady, 7*, 83–105.

Duval, R. (2006). Quelle sémiotique pour l'analyse de l'activité et des productions mathématiques ? *RELIME. Revista latinoamericana de investigación en matemática educativa, 9*(1), 45–82.

Freiman, V., Martinovic, D., & Karadag, Z. (2009). Decouvrir le potentiel´educatif du logiciel dynamique GeoGebra : Communaute de collaboration et de partage. *Bulletin AMQ Association Mathematique du Quebec, 49*(4), 34–49.

Grinshkun, V., & Osipovskaya, E. (2020). Teaching in the fourth industrial revolution: Transition to education 4.0. In *Proceedings of the 4th international conference on informatization of education and E-learning methodology: Digital technologies in education (IEELM-DTE 2020)*. Retrieved from http://ceur-ws.org, 2770.

Jacinto, H., & Carreira, S. (2017). Mathematical problem solving with technology: The techno-mathematical fluency of a student-with-GeoGebra. *International Journal of Science and Mathematics Education, 15*(6), 1115–1136. https://doi.org/10.1007/s10763-016-9728-8

Mariotti, M. A., & Maracci, M. (2010). *Les artefacts comme outils de médiation sémiotique : Quel cadre pour les ressources de l'enseignant ?* Presses Universitaires de Rennes et INRP.

Minh, T. K. (2012). Les fonctions dans un environnement numérique d'apprentissage: Étude des apprentissages des élèves sur deux ans. *Canadian Journal of Science, Mathematics and Technology Education, 12*(3), 233–258.

Ministère des Enseignements Secondaires (2016). Programmes de l'enseignement secondaire générale : toutes disciplines second cycle.

Naidoo, J., & Singh-Pillay, A. (2020). Exploring mathematics teachers' professional development: Embracing the fourth industrial revolution. *Universal Journal of Educational Research, 8*(6), 2501–2508.

Schwab, K. (2017). *The fourth industrial revolution*. Currency.

Vasquez, D. (2015). *Enhancing student achievement using GeoGebra in a technology rich environment* (PhD Thesis). California State Polytechnic University, Pomona.