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Implementation of a Dynamic and Multipolar Approach in the Teaching of Chemistry in the 5th Grade of the Malagasy Education System

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Abstract

In order to improve quality of learning in chemistry in the 5th grade, a new curriculum based on a dynamic and multipolar approach was designed and applied in two classrooms at the Lycée Toamasina II, mobilizing available resources. The evaluation of learning allowed noticing a better appropriation of the notional contents, and a mastery of disciplinary skills by students. Moreover, students developed 21st century skills during the learning process. However, the proficiency level could be improved by applying the proposed approach all along the schooling of the pupils, from secondary school to higher education.

Keywords

Learning Process, Dynamic and Multipolar Approach, Proficiency Level, Quality of Learning

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1. Introduction

As part of the application of the quality approach in learning, several categories of processes contribute to pedagogical development and pedagogical innovation [1]. First, the main process is to improve quality of learning. Then, the steering process to ensure the desirability of design is the search for the effectiveness of the teaching and the autonomy of the learner, the second steering process is the feasibility of education and training by the use of ICT, and the last steering process is to make learning viable by combining the goal-oriented pedagogy and the skill-based approach. Finally, the support processes are technological and pedagogical communication, collaborative learning and flipped classroom. At the application level, several operational processes revolve around the implementation of a curriculum

After the diagnosis of the various shortcomings identified in the implementation of the goal-oriented pedagogy in the teaching of chemistry in the 5th grade [2], a new teaching curriculum has been developed, using a dynamic and multipolar approach. This curriculum integrates the inputs needed to apply the mapping process related to educational development and pedagogical innovation, new outputs of chemistry learning, which correspond to a decomposition of the specific objectives of the program of the Malagasy education system in terms of disciplinary skills, as well as the corresponding activities that will enable students to follow an individualized path.

In order to measure the impact of the implementation of this curriculum on the quality of student learning, it was applied in chemistry courses during the 2017-2018 school year in two 5th grade classes at Lycée Toamasina II. At the end of the experiment, the expectations are a better appropriation of the disciplinary contents enacted by the program, and the acquisition of skills which the student will be able to reinvest in other scholar contexts and extracurricular contexts.

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2. Implementing the Curriculum

Since the chemistry teaching program in the Malagasy education system is based on the goal-oriented pedagogy, it has been essential to break down the specific objectives into disciplinary skills whose evaluation is more operational in the context of a differentiated teaching course. Then, a curriculum was established and implemented during the experimentation. Lastly, skill proficiency levels were defined according to the behaviors expected from students during learning.

2.1. Definition of Disciplinary Skills to Evaluate

A specific objective is a statement of expected effects in terms of student change, achieved through a set of defined and phased learning activities at multiple levels [3-4]. A skill is a process of integrated and functional mobilization of cognitive resources presupposing knowledge in a determined notional or disciplinary field, and intellectual and global capacities to face singular situations, contextualized problems or projects to realize [5-11].

To develop the curriculum to be implemented during chemistry teaching in the 5th grade, each specific objective of the curriculum is broken down into disciplinary skills derived from the articulation between Bloom's taxonomic model and the taxonomy of Tirsur, whose progression leads to different levels to reach the objective. The deployment of a suite of skills following this progression allows the student to acquire the disciplinary content which corresponds to the specific objective. In fact, the decomposition of specific objectives into disciplinary skills facilitates pedagogical differentiation and assessment of learning outcomes.

Table 1. Decomposition of specific objectives into disciplinary skills.

Specific objectives	Skills	Contents
The student must be able to explain what the chemical element is	1. Implement a protocol to verify the conservation of an element 2. Experimentally remove the notion of chemical element 3. Appropriate of the notion of chemical element	Matter and its chemical transformations 1. Oxidation of copper 2. Conservation of the iron element
The student must be able to represent a chemical element by its symbol	1. Know the symbol of some chemical elements 2. Know that the atomic number characterizes the chemical element	1. Symbol of elements
The student must be able to describe the structure of the atom	1. Know the constitution of an atom and its nucleus 2. Differentiate the mass number from the atomic number 3. Know that two isotopes differ in their number of neutrons 4. Know and use the symbol of the atomic nucleus	1. Structure of the atom 2. Isotopes
The student must be able to write the electronic forms of the first 20 elements	1. Write the electronic formulas of the first 20 elements 2. Distributing the electrons in quantum boxes 3. Identify the outer layer 4. Count the electrons of the outer layer 5. Write Lewis's representation of an atom 6. Calculate the mass of an atom	1. Electronic structure and Lewis representation of the atom 2. The periodic classification of chemical elements 3. Masses of a proton, a neutron and an electron
The student must be able to give the characteristics of the elements of the family of alkalis, halogens and inert gases	1. Classify the chemical elements according to their properties 2. Experimentally determine the chemical properties of a chemical family 3. Write the electronic formulas of the first 20 elements 4. Distributing the electrons in quantum boxes 5. Identify the outer layer 6. Count the electrons of the outer layer 7. Identify the elements of the same chemical family 8. Locate, in the periodic table, the families of alkalis, halogens and inert gases	1. Properties of halogens 2. Properties of alkalis and inert gases 3. Use of halogens, alkalis and inert gases 4. The chemical families and their properties 5. Location of chemical elements in the periodic table
The student must be able to locate an element in the classification and justify the change of line	1. Write the electronic formulas of the first 20 elements 2. Distributing the electrons in quantum boxes 3. Identify the outer layer 4. Count the electrons of the outer layer 5. Determine the atomic number of an element from its electronic structure	1. Electronic structure and representation of Lewis
The student must be able to explain the formation of a monoatomic ion	1. Write the electronic formulas of the first 20 elements 2. Identify the outer layer 3. Count the electrons of the outer layer 4. Know and apply the rules of the duet and the octet to account for the charges of the usual monoatomic ions. 5. Write the equation of formation of a monoatomic ion 6. Calculate the charge of an ion	Ion and ionic compounds: 1. Duet and byte rule 2. Monatomic ions 3. Elementary electric charge 4. Formation of monoatomic ions 5. Formation of ionic compounds
The student must be able to give examples of polyatomic ions	1. Distinguish polyatomic ions from monoatomic ions 2. Give examples of polyatomic ions	1. Polyatomic ions
The student must be able to identify some ions	1. Know the tests of identification of some ions 2. Implement a protocol to identify ions	1. Identification tests of some ions

Specific objectives	Skills	Contents
The student must be able to explain the formation of a molecule	1. Write Lewis's representation of an atom 2. Establish a covalent bond between two atoms 3. Write the developed formula of a molecule 4. - Know that a formula can correspond to several semi-developed formulas	Molecules 1. Molecules and covalent bonds 2. Formation of molecules
The student must be able to define the mole	1. Know the number of Avogadro 2. Take ownership of the notion of quantity of material	Balance equation of a chemical reaction 1. The mole
The student must be able to define the molar mass of a body	1. Know that the atomic molar mass characterizes the chemical element 2. Calculate a molecular molar mass from atomic molar masses 3. Determine a quantity of material knowing the mass of a solid or the volume of a gas	1. Molar mass of a solid 2. Molar volume of a gas
The student must be able to balance an equation and interpret it in mole and mass	1. Realize the combustion of butane 2. Write the equation of a chemical reaction with the correct stoichiometric numbers 3. Use chemical equations to solve chemistry problems	1. Combustion of butane 2. Balance equation of a chemical reaction
The student must be able to interpret the dissolution of sodium chloride in water	1. Prepare a concentration solution given by dissolution or dilution 2. Know that a solution can contain molecules or ions. 3. Know that the concentration of a solution in dissolved species can be expressed in $g.L^{-1}$ or in $mol.L^{-1}$. 4. Know and exploit the expression of the mass or molar concentration of a dissolved molecular or ionic species.	Ionic aqueous solutions 1. Solute, solvent and solution 2. Solubility of a solute - Saturated solution 3. Mass concentration 4. Molar concentration
The student must be able to translate a dissolution into a chemical equation	1. Write the equation of a chemical reaction with the correct stoichiometric numbers 2. Use chemical equations to solve chemistry problems	1. Preparation of a solution by dissolution of a solid and by dilution

2.2. Implanted Curriculum

As part of the teaching of chemistry in two 5th grade classes at Lycée Toamasina II, a public educational institution of the Malagasy education system, an implemented curriculum was adapted to the means available to students. Indeed, the establishment has 50 tablets in which are integrated resources on the essential notions corresponding to the programs of Malagasy high schools; these tablets also allow students to connect to the internet to search for other resources. The institution's library has 36 chemistry books that can be used to deepen courses and offer practice exercises.

At the beginning of the school year, a session was organized to teach students to use the internet for educational purposes. To facilitate technological and educational communication, students have opened Gmail accounts through which they can communicate with each other and with the teacher, and pool their work. In addition, the use of the social network Facebook was encouraged; a group was created for students in both classes who owned an account in this social network, and sending private messages to the teacher is allowed for discussions of educational interest.

The teacher establishes a calendar of the activities to be carried out which is completed as the program progresses; this calendar is viewed by students in the Google Classroom option, which also allows the student to post comments or questions, and to submit the homework online, in order to optimize the face-to-face learning time. To share digital resources, a Drive was opened, in which the teacher posts the course notes, video clips, and internet links that students should consult before each session. The Google Form option allows the teacher to create the placement questionnaires that students must complete before coming to class. The use of these options facilitates the collaborative work of students, such as helping each other for individual homework outside the classroom and preparing group work such as presentations.

In order to enable the student to acquire the skills defined from the decomposition of the specific objectives, each activity is built around disciplinary contents prescribed in the program. The description of the learning modalities allows identifying the behaviors which must be observed in the learner during each activity.

Table 2. Implanted curriculum.

Session	Activities	Contents	Mobilized resources	Learning modalities
1	Practical work	Matter and its chemical transformations 1. Oxidation of copper	Video capsule Experiment protocol Review of the experience	Lesson provided before session Group work Magisterial presentation
2	Practical work	1. Conservation of the iron element	Iron cycle	Investigative approach
	Application	1. Symbol of the elements 2. Structure of the atom 3. Isotopes	Video capsule Summary of essential concepts	Lesson provided before session Positioning questionnaire Group work
3	Tutorials	1. The periodic classification of chemical elements	Table of periodic classification of chemical elements	Literature search
		1. Electronic structure and Lewis	Video capsule	Lesson provided before session

Session	Activities	Contents	Mobilized resources	Learning modalities
		representation of the atom	Summary of essential concepts	Group work Magisterial presentation
4	Practical work	1. Properties of halogens	Experiment protocol Review of the experience	Group work Magisterial presentation
5	Presentation by students	1. Properties of alkalis and inert gases 2. Use of halogens, alkalis and inert gases	Presentation plan	Literature search
	Lecture	1. The chemical families and their properties	Video capsule Summary of essential concepts	Lesson provided before session Magisterial presentation
	Tutorials	2. Location of chemical elements in the periodic table	Table of periodic classification of chemical elements	Group work
6	Remediation and deepening exercises	1. Electronic structure and representation of Lewis 2. Location of chemical elements in the periodic table 3. Elementary electric charge 4. Masses of a proton, a neutron and an electron	Values of the elementary electric charge, the masses of a proton, a neutron and an electron	Lesson provided before session Individual work Peer tutoring Personalized support
7	Formative evaluation	Matter and its chemical transformations	Mind map	Group work Class report
8	Examination	Matter and its chemical transformations	Homework preparing examination	Individual work Collective correction
9	Lecture	Ions and ionic compounds 1. Duet and byte rule 2. Monatomic ions and polyatomic ions	Video capsule Summary of essential concepts	Lesson provided before session Positioning questionnaire Magisterial presentation
	Presentation by students	Examples of monoatomic ions and polyatomic ions	Presentation plan	Literature search
10	Tutorials	1. Formation of monoatomic ions 2. Formation of ionic compounds	Mind map	Group work Class report
11	Tutorials	1. Formation of monoatomic ions 2. Formation of ionic compounds 3. Charge of an ion	Mind map	Positioning questionnaire Individual work Peer tutoring Personalized support
12	Presentation by students	1. Identification tests of some ions	Presentation plan	Literature search
	Practical work	1. Identification tests for ions contained in mineral water	Course notes	Group work
	Formative evaluation	1. Identification tests of some ions		Evaluation questionnaire
13	Application	1. Formation of monoatomic ions 2. Formation of ionic compounds 3. Identification tests of some ions		Individual work Peer tutoring Personalized support
14	Examination	Ions and ionic compounds	Homework preparing examination	Evaluation questionnaire Peer evaluation
15	Formative evaluation Remediation exercises	Molecules 1. Electronic structure and representation of Lewis		Positioning questionnaire Peer tutoring Personalized support
	Tutorials	1. Molecules and covalent bonds 2. Formation of molecules	Summary of essential concepts	Lesson provided before session Magisterial presentation Group work
16	Tutorials	1. Formation of molecules	Mind map	Group work Class report
	Remediation exercises	1. Formation of monoatomic ions 2. Formation of ionic compounds 3. Identification tests of some ions	Memorisation sheet	Individual work Peer tutoring Personalized support
17	Examination	Ions and ionic compounds Molecules	Homework preparing examination	Individual work Collective correction
18	Tutorials	Equation of a chemical reaction 1. The mole 2. Molar mass of a solid or a liquid 3. Molar volume of a gas	Video capsule Summary of essential concepts	Lesson provided before session Magisterial presentation Individual work
19	Presentation by students	1. Presentation of different chemical reactions	Presentation plan	Literature search Group work
	Practical work	1. Combustion of butane	Experiment protocol	Group work
20	Tutorials	1. Equation of a chemical reaction	Method-sheet	Magisterial presentation Individual work Collective correction
	Tutorials	1. Solving chemistry problem	Method-sheet	Magisterial presentation Group work

Session	Activities	Contents	Mobilized resources	Learning modalities
21	Remediation exercises	1. Equation of a chemical reaction	Method-sheet	Individual homework Personalized support
	Deepening exercises	2. Solving chemistry problem	Method-sheet	Group work
22	Remediation exercises	1. Solving chemistry problem	Method-sheet	Individual work Peer tutoring Personalized support
23	Formative evaluation	1. Solving chemistry problem	Method-sheet	Individual work Collective correction
24	Formative evaluation Remediation exercises	Ionic aqueous solutions 1. Formation of ionic compounds	Memorisation sheet	Positioning questionnaire Personalized support
	Tutorials	1. Solute, solvent and solution 2. Solubility of a solute - Saturated solution 3. Mass concentration 4. Molar concentration	Video capsule Summary of essential concepts	Lesson provided before session Magisterial presentation Individual work Collective correction
25	Presentation by students	1. Protocol for preparing a solution by dissolving a solid	Presentation plan	Literature search Group work
	Practical work	1. Preparation of a solution of sodium chloride with a known concentration by dissolution	Experiment protocol	Group work
26	Remediation exercises	1. Solving chemistry problem	Method-sheet	Individual work Personalized support
	Deepening exercises	1. Solving scientific problem	Scientific problem sheet	Group work
27	Tutorials	1. Mass concentration 2. Molar concentration	Summary of essential concepts	Magisterial presentation Group work
28	Presentation by students	1. Protocol for the preparation of a solution by dilution	Presentation plan	Literature search Group work
	Practical work	1. Preparation of an orange juice by diluting a concentrated solution of orange juice of known concentration	Experiment protocol	Group work
29	Tutorials	1. Mass concentration 2. Molar concentration	Method-sheet	Individual work Personalized support
30	Remediation exercises	1. Solving chemistry problem	Method-sheet	Individual work Personalized support
	Deepening exercises	1. Solving scientific problem	Scientific problem sheet	Group work
31	Examination	1. Solving chemistry problem 2. Equation of a chemical reaction 3. Ionic aqueous solutions	Homework preparing examination	Individual work

2.3. Evaluation Method

Skill's assessment was done taking into consideration the progress of each student on several sessions. An evaluation grid is given to each student at the beginning of the year, checked at the beginning of the session so that the teacher directs him to the work he has to do, and completed at the end of the session by the teacher who indicates to the student the points that he must revisit or deepen. The level of proficiency of the student on each skill is evaluated on 4 levels:

a. A: the student masters the skill by performing the task associated with it satisfactorily according to the specified criteria, independently, or with the help of his peers or with one or two interventions by the teacher, concerning difficulties identified and clarified by the student and to which he answers almost by himself;

b. B: the student completes the requested task satisfactorily according to the specified criteria, with the help of his peers, or one or two interventions by the teacher concerning difficulties or errors not identified by the student, but resolved by himself in an autonomous way, after having thought about it;

c. C: the student is stuck in his process and uses the input of his peers or the teacher;

d. D: the student is unable to perform the requested task despite the help of his / her peers and the teacher, thus demonstrating insufficient proficiency of the required skill.

3. Results

The curriculum was implemented in two 5th grade classes at Lycée Toamasina II, a public educational institution of the Malagasy education system, composed respectively of 35 and 44 students.

3.1. Evaluation of Disciplinary Skills

The results noted in the table for each skill were obtained after all the activities in which they were developed.

Table 3. Results at Lycée Toamasina II.

Skills	Proficiency level			
	A	B	C	D
Implement a protocol to verify the conservation of an element	60,76%	25,31%	13,93%	00,00%
Experimentally release the notion of chemical element	20,25%	39,24%	22,79%	17,72%
Appropriate the notion of chemical element	13,93%	15,19%	31,64%	39,24%
Know the symbol of some chemical elements	78,48%	21,52%	00,00%	00,00%
Know that the atomic number characterizes the chemical element	60,76%	25,31%	13,93%	00,00%
Differentiate the mass number from the atomic number	60,76%	25,31%	13,93%	00,00%
Know that two isotopes differ in their number of neutrons	60,76%	25,31%	13,93%	00,00%
Know and use the symbol of atomic nucleus	46,83%	31,64%	15,19%	6,34%
Know the constitution of an atom and that of its nucleus	46,83%	31,64%	15,19%	6,34%
Write the electronic formulas of the first 20 elements	83,91%	16,09%	00,00%	00,00%
Spread the electrons in quantum boxes	86,07%	13,93%	00,00%	00,00%
Identify the outer layer	100%	00,00%	00,00%	00,00%
Enumerate the electrons of the outer layer	100%	00,00%	00,00%	00,00%
Write Lewis's representation of an atom	39,24%	25,31%	21,52%	13,93%
Calculate the mass of an atom	10,12%	12,66%	15,19%	62,03%
Determine the atomic number of an element from its electronic structure	86,07%	13,93%	00,00%	00,00%
Experimentally determine the chemical properties of a chemical family	13,93%	17,72%	39,24%	29,11%
Classify chemical elements according to their properties	46,83%	31,64%	15,19%	6,34%
Identify the elements of the same chemical family	78,48%	21,52%	00,00%	00,00%
Locate, in the periodic table, families of alkalis, halogens and inert gases	86,07%	13,93%	00,00%	00,00%
Know and apply duet and byte rules to account for typical monatomic ion charges	21,52%	30,02%	25,31%	23,15%
Write the equation of formation of a monoatomic ion	21,52%	30,02%	25,31%	23,15%
Give examples of polyatomic ions	43,03%	31,64%	25,33%	00,00%
Distinguish polyatomic ions from monoatomic ions	43,03%	31,64%	25,33%	00,00%
Calculate the charge of an ion	31,64%	39,24%	29,12%	00,00%
Know the tests of identification of some ions	13,93%	46,83%	25,33%	13,91%
Implement a protocol to identify ions	43,03%	35,45%	21,52%	00,00%
Establish a covalent bond between two atoms	100%	00,00%	00,00%	00,00%
Write the structural formula of a molecule	39,24%	25,31%	21,52%	13,93%
Know that a formula can correspond to several semi-developed formulas	10,12%	12,66%	15,19%	62,03%
Know the number of Avogadro	13,93%	17,72%	39,24%	29,11%
Appropriate the notion of quantity of matter	29,11%	43,03%	21,52%	6,34%
Know wthat the atomic molar mass characterizes the chemical element	100%	00,00%	00,00%	00,00%
Calculate a molecular molar mass from atomic molar masses	100%	00,00%	00,00%	00,00%
Determine an amount of material knowing the mass of a solid or the volume of a gas	86,07%	13,93%	00,00%	00,00%
Realize the combustion of butane	21,52%	39,24%	35,45%	3,79%
Write the equation of a chemical reaction with the correct stoichiometric numbers	86,07%	13,93%	00,00%	00,00%
Use chemical equations to solve chemistry problems	21,52%	30,02%	25,31%	23,15%
Prepare a solution of concentration given by dissolution or dilution	43,03%	31,64%	25,33%	00,00%
Know that a solution may contain molecules or ions	15,19%	17,72%	39,24%	27,85%
Know that the concentration of a dissolved solution can be expressed in $g.L^{-1}$ or in $mol.L^{-1}$	39,24%	25,31%	21,52%	13,93%
Know and exploit the expression of the mass or molar concentration of a dissolved molecular or ionic species	17,72%	56,96%	11,39%	13,93%

The memorization of chemical symbols, the electronic structure and the atomic number, the location of the chemical elements in the periodic table, the establishment of covalent bond between two atoms and the calculation of molecular molar masses are well mastered by the students. The implementation of protocols to check the conservation of the elements was done in two sessions and was followed closely by the teacher, explaining a good result compared to the other experimental skills, the determination of the properties of the chemical families gives results which are relatively low, but the following experimental skills control shows a progression of students. The exploitation of the formulas in the exercises is mastered by the majority of the learners, whereas the skills corresponding to the level of analysis and synthesis in the taxonomy of Bloom [12] are acquired only by students with high performance.

3.2. Development of Transversal Skills

Students arriving in the 5th grade at Lycée Toamasina II come from the rural outskirts of Toamasina, and for the most part have no computer skills. Internet introductory sessions carried out outside the usual courses and the deployment of digital tools whose tablets helped develop digital skills among students. Students learned to read a digital file, enter text with seizure software, browse the Internet to search, send and receive emails, use a social network, and different possibilities offered by their electronic accounts like data storage, video clip download, and instant chat.

Through the activities which were implemented, they discovered new skills which will be useful for their university studies and their future professional integration. Information management has developed as students were encouraged to research and select the essential elements to retain from the course or to present at a presentation. The presentations allowed the students to take initiatives and showcase their creativity, the engagement of debates at the end of the presentations gave the opportunity to the students to exchange their ideas and to confront their arguments with those of the others. In relation to disciplinary skills at the level of analysis and synthesis, only the best students demonstrated creativity and critical thinking through the proposed in-depth exercises. Collaborative learning was particularly appreciated as it fostered the growth of good students and a sense of achievement among struggling students.

Although they never used such skills in their schooling, students quickly assimilated the new work methods, and found themselves motivated to engage in learning. However, students are still struggling to work independently, they often seek help from their peers or the assurance given by the coaching of the teacher.

4. Discussions

The heavy content of the chemistry program alters the quality of learning. Indeed, the concepts that students must learn are numerous and do not allow to invest a lot of time in their application. The decomposition of specific objectives into disciplinary skills helped a lot in designing activities which really benefit students. Student learning was focused on the acquisition and retention in long-term memory of the essential disciplinary concepts they will need in the further course of their schooling.

The flipped classroom method allowed the sessions to be unloaded from the lengthy lecture presentations of the lessons through the use of video clips and summaries of essential concepts which could be consulted before the class. The use of online communication tools, including the instant messaging service and the Facebook discussion group, helped to better support students by answering their questions outside the classroom, and to better prepare masterful presentations based on difficulties expressed by students. The face-to-face sessions were used to answer the majority of the questions asked before the course and to explain the essential points, and allowed to focus on the execution of the application exercises, which enabled the students to develop the essential skills they must develop in the 5th grade and they will have to reinvest in the upper classes.

The provision of various resources facilitated the retention of knowledge and the development of skills. Indeed, the students appreciated that the lessons were reduced to the essentials using the course summaries and the memorization sheets which facilitated their learning. Mental mapping at the end of each chapter provided students with benchmarks of key points to remember, and facilitated their review for summative evaluations. To solve the problems of chemistry, the use of method-sheets facilitated the mobilization of the formulas, and helped to encourage the commitment of the students in the accomplishment of the task.

Student motivation was easily stimulated by contextualized activities. Indeed, the activities and the application exercises were formulated so that they are directly related to situations which can be lived daily by the pupils, or problems in relation with professional circles. Contextualization gave meaning to learning, especially through the practical applications of the concepts in the lesson, and aroused the interest and curiosity of students. Literature searches, resource sharing and presentations were opportunities to value students' contributions to building knowledge.

Improving the proficiency level of skills is the result of pedagogical differentiation. Indeed, the student's path was personalized as much as possible. For some sessions, several types of activities were carried out according to the needs of the students, and the pace of skill development and knowledge acquisition depended on the proficiency level of each student. In particular, the positioning questionnaires and the formative evaluations enabled the teacher to form support groups and to propose remedial exercises to be carried out in his presence or at home. However, the constraints related to the implementation of the program forced reserving scientific problem solving to the best students.

In the chemistry program of the Malagasy educational system, few notions can be acquired through the implementation of practical work. However, we implemented simple experiments based on material and pedagogical possibilities, allowing students to develop some experimental skills related to the program. The realization of experimental activities gave students the opportunity to engage in a real investigation and construction of knowledge, and boosted their motivation in learning chemistry. Despite the organization of practical sessions throughout the school year, students find it difficult to work independently and to draw conclusions from the experiences they performed.

In terms of cross-curricular skills, their development is done through habits rooted in learning methods. Collaborative learning was assimilated and appreciated, and peer tutoring contributed to the sense of achievement of struggling students and enhancement of the skills of successful students. As students are not used to expressing their ideas, confronting different points of view and questioning their knowledge, the development of critical thinking and analytical skills should be engaged in the lower classes, and developed collaboratively with other subjects, because the amount of time allocated to teaching chemistry in the 5th

grade is not enough.

On the other hand, most students learned to use new technologies during chemistry courses, and all students discovered for the first time the pedagogical possibilities offered by digital tools, while digital skills are not part of the chemistry teaching, but should be developed throughout the student's curriculum from the lower classes. A better mastery of information and communication technologies would encourage creativity and in-depth study topics from students.

Teacher coaching was also essential in the learning process. Indeed, the role of the teacher was limited to indicating the essential points to remember, giving benchmarks on the stages of activities, validating the success of each step and challenging each difficulty encountered without indicating the way of resolution. The fact that the teacher is available to support students in case of difficulty developed a sense of self-confidence and confidence in their success. Students understood that their success depends only on the effort they make in carrying out the work required by the teacher, but that they will always have a remedy when they encounter a problem in their path.

5. Conclusion

As part of the application of a dynamic and multipolar approach in the teaching of chemistry in the 5th grade, the specific objectives of the program in the Malagasy education system were broken down into disciplinary skills. This decomposition facilitates the implementation of a training curriculum based on activities aimed at improving the quality of learning of the student through pedagogical development and pedagogical innovation. The training curriculum includes the learning methods and the resources mobilized at each stage of learning, and serves as a dashboard facilitating the assessment of each student's achievements, the personalization of teaching and the remediation of difficulties encountered by the students.

The experimentation of the curriculum implemented in two classes of 5th grade at the Lycée Toamasina II showed a good appropriation of the notional contents which are the subject of the chemistry teaching and a satisfactory mastery of the disciplinary skills on the whole of the school year. However, the development of transversal skills seemed difficult. Indeed, the lack of habit in the use of digital tools in the school context was a challenge to overcome in obtaining optimal results, and students were not accustomed to being the main actors of their learning, especially through the expression of their creativity, even if the best students were able to develop a critical spirit. Only collaborative learning produced the desired effects from the beginning of the activities, including the development of empathy, the feeling of progression among students in difficulty, the sense of value among high achievers.

Notwithstanding the good results obtained in the mastery of the disciplinary skills, it turned out that the heaviness of the program and the plethoric number of the notions that the pupils must acquire constituted obstacles to the optimization of the application of a dynamic and multipolar approach based on processes. In fact, improving the quality of learning should also take into account the focus of teaching on content and skills that really make sense of the student's learning and which will be used in the future of his school curriculum. The teaching of chemistry in the 5th grade should move towards a preparation of the student to university studies and enroll in a comprehensive training contributing to the professionalization beginning at the high school level.

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