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Institutional Perspectives for the Integration of the Spreadsheet in Mathematics Learning: The Case of French Curriculums and Assessments

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Keywords
spreadsheet, mathematics curriculums, assessment, mathematics education, integration of ICT

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Abstract
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Keywords: spreadsheet, mathematics curriculums, assessment, mathematics education, integration of ICT

1. INTRODUCTION
Rapid development of Information and Communication Technologies (ICT) today has made the use of these tools in education indispensable. Recent studies on the use of technology in education focuses on effective integration of these tools in education.

International Society for Technology in Education (ISTE) [1] defines this integration as embedding technology in learning process and making it a part of instructional functions to promote learning in a particular content area or interdisciplinary context so that it becomes accessible like other educational tools. The National Center for Education Statistics (NCES) [2] considers integration in a broader context and defines it as combining technological resources and technology-based applications in daily life, work and school management.

Integration of ICT in mathematics education has been studied over the last 30 years. In their review of publications on this subject, Lagrange et al. [3] point out that the “period from 1994 to 1998 appeared particularly worthy of a study, because during these years the classroom use of technology became more practical, and literature matured, often breaking with initial naive approaches” (p. 238). They also suggest that the most commonly used teaching tools in the publications were Computer Algebra Systems (CAS) and graphing systems while the least used tool was the spreadsheet (Table 1).
These research results are reflected in the current situation in schools. In other words, despite the potential that the spreadsheet has for enriching teaching-learning process, it has not been used in schools as much as other tools such as dynamic geometry software and calculators in particular. For example, Sugden [4] refers to the situation in Australia as follows:

“What is used in secondary schools? There seems to be a love affair with graphics calculators (GCs) in Australia. When superior tools such as Excel are widely available, it is difficult to understand the GC choice.” (p. 68)

On the other hand, Calder [5] argues that the spreadsheet has potential to be used in various areas in mathematics education such as development of algebraic thinking, the multiple representations (visual, symbolic and numerical) of mathematical concepts, exploration of ideas and mathematical concepts in problem solving process, and positive motivational effects in classroom programs. Also, it has been recently shown [6] that special interactive tools which illustrate mathematical theoretical concepts can be built within spreadsheets so as to provide the student with technology enhancement that simplifies the doing of quantitative methods, and thus enhances (optimizes) learning.

Sugden [4] suggests that showing the potential of the spreadsheet for mathematics education is no longer considered to be satisfactory for adoption as there are already enough studies on this subject, so what is actually needed now is to convince institutions to adopt the use of the spreadsheet in education.

Institutions’ attitudes and approaches towards the use of technology are reflected in their standards and curriculums, textbooks, assessments and the experiments they carry out. Among these factors, which affect integration of technology [7], this study is limited to the investigation of curriculum ve assessments.

1.1 Curriculums and ICT

Roblyer [7] argues that it is impossible for students to achieve the expected outcomes related to the integration of technology without the subject area and that the expected outcomes should be a part of content area curriculums:

“Therefore, it is critical to situate NETS (The National Educational Technology

Table 1: Tools used in the studies between 1994 and 1998 [3]

<table>
<thead>
<tr>
<th>Tools</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreadsheet</td>
<td>39</td>
<td>7.7</td>
</tr>
<tr>
<td>Microworld</td>
<td>50</td>
<td>9.9</td>
</tr>
<tr>
<td>Calculator</td>
<td>80</td>
<td>15.8</td>
</tr>
<tr>
<td>Technology (Tutorial, EIAO, Internet, Multimedia, Hypermedia)</td>
<td>93</td>
<td>18.4</td>
</tr>
<tr>
<td>Geometry software</td>
<td>106</td>
<td>21.0</td>
</tr>
<tr>
<td>CAS and grapher</td>
<td>138</td>
<td>27.2</td>
</tr>
</tbody>
</table>
Standards) for students in content area curriculum in ways that support both the subject area content and the technology skills and that align with the shared vision. So implementation can lead to goals such as enhanced learning and motivation. Fortunately, many content area standards already address appropriate technology resources and applications and others seem poised to do so. Thus, this essential condition is met best when technology and content area standards are designed to support each other.” (pp. 63)

According to a study by the OECD (The Organization for Economic Co-operation and Development) in 2001, many countries realizing the importance of the use of technology in education made curriculum changes in a way that emphasized the advantages and potential of technology. The changes made for the integration of technology indicate that the approaches adopted by countries are different from each other [8]. According to Wong [8], information technology (IT) is employed in mathematics curriculums in three ways: a) IT is regarded as integral to effective teaching and learning of mathematics b) IT is positioned as an enhancement to learning which could enrich the learning experience of students, and c) Mathematics can play the role of developing IT literacy among students.

**Pragmatic and epistemic values in curriculum**

The curriculum revisions made based on the assumption that integration only means meeting material requirements play a key role in the failure of technology integration [9]. It is important to establish the equilibrium between technical work and conceptual work in technology-aided learning environments in teaching mathematics [9]. This equilibrium can be defined based on the two values of technology suggested by Artigue [10]: pragmatic value and epistemic value. Pragmatic value represents the practical and productive aspects of technology while epistemic value refers to the effect of technology on learning the subject studied. For example, copying by dragging in a spreadsheet allows for multiple calculations at a time. This is the pragmatic value of this technique while using spreadsheets. This procedure generates a recursive sequence which is a part of the explained theory. This shows its epistemic value [11]. Artigue [10] also claims that the emphasis is usually on pragmatic value with respect to the use of technology in education, but epistemic value is not adequately dealt with.

In this regard, emphasizing the importance of technology in curriculums in a way that establishes the equilibrium between its pragmatic and epistemic values is essential for the success of integration.

1.2. Assessments and ICT

Another factor affecting integration is national assessments. Trouche [12] suggests that these examinations are important from two points of view:

“– it indicates what an institution considers it necessary for students to know,
allowing the ‘hard core’ of the curriculum and related official prescriptions to be determined;

- it allows eventual uncertainties (corresponding, for example, to what an institution requires to be taught, but not to be assessed) to be identified. “ (p. 29)

There are studies about the effects of the use of technology in assessments, especially about the effects of CAS. For example, Monaghan [13] examines A-level exams in the UK, MacAogáin [14] examines Irish Leaving Certificate Examination, and Flynn & McCrae [15] review the Australian perspective. There are also cross-country comparisons on this subject. For example, Brown [16] examines the exams in the USA, Australia and Denmark, and Drijvers [17] examines those in some European countries. Some researchers such as Flynn & Asp [18] and Ball & Stacey [19] examine the effects of the use of CAS exams on students.

In addition, some studies classify exams or exam questions. While Kokol-Voljc [20] classifies classic exam questions based on their usability in CAS environment, Kutzler [21] prefers to make a classification based on the role of the CAS in solutions. Kutzler first looks at how significant the use of the CAS is (primary versus secondary use), and then he looks at how well the student needs to know the CAS (routine versus advanced use). MacAogáin [14] classifies questions as trivial, easy, difficult or CAS-proof. He proposes a calculation of an “index of suitability” for examinations that could be applied to any examination. Drijvers [17], on the other hand, categorizes the approaches adopted in exams into four groups: technology partially prohibited; technology allowed, but benefits avoided; technology recommended and useful, but no added marks; and technology obligatory and rewarded.

Although there are many studies on this subject, how to assess students’ mathematical outcomes in a technology supported environment is still a problematic issue.

1.3. Why French Curriculum and Assessments?

Wong [8] claims that an official curriculum is mandatory in some countries while it is not in other countries. Having a national curriculum in its education system for many years, France has an educational structure that is different from many other western countries [8]. Especially the changes in high school mathematics curriculums in 2000 emphasized the use of technology in the national curriculum. Since the 70s, when calculators began to be used as the first technological tools in education, there has been a significant improvement in French curriculums in terms of the integration of ICT in mathematics education. While technology was regarded as a tool which helped to do calculations in 1971, it began to be used in observation, hypothesis, and verification methods after 1982. Since 2000, on the other hand, technological tools have been considered as the basic element of all mathematical processes (e.g. hypothesis and verification) and development of a rigorous mind in mathematics [12]. The changes made in 2000 in the French mathematics curriculums and
acknowledgment of “mastering common information and communication technologies” as one of the seven primary competencies [22] reflect the determination of the French Department of National Education and Research about the integration of technology into mathematics education.

In France, in line with the relevant curriculums, some national exams at both secondary school (collège) and high school (lycée) levels assess student competence in the use of technology in solving mathematical problems. The most significant one among these exams is the Baccalaureate, the exam for high school graduation and university entrance. In these exams, students have been allowed to use basic calculators with four operations since 1986 and graphing calculators since 1999. Another national exam in France is the “Practical Test of Mathematics” (PTM) (l’épreuve pratique des mathematiques). The PTM, which was administered to high school senior science students as the pilot implementation of a new examination model in 2006, was later expanded and it was introduced in 3eme (14-15 ages) and 2nde (15-16 ages) grade levels (see Table 2). The aim of this exam is to measure students’ skills to use calculators and certain special software in mathematics and their competence to study a mathematical problem using ICT (p.6)[23]. “Early Baccalaureate Exam of Mathematics and IT”(EBEMIT) (l’épreuve anticipée de mathématiques et informatique du BAC L) taken by High School 1st grade Literary (1ere L) students also has a special importance. This exam assesses the outcomes with respect to the use of the spreadsheet. However, this is a paper-pencil test.

Also, in France, students may sit an exam called “Information Technology and Internet Proficiency Certificate: B2i” (Brevet Informatique et Internet: B2i) at primary school, secondary school, and high school education. The aim of this assessment is to recognize the technological abilities gained by students throughout their school lives – primary school, secondary school and high school –, to promote effective use of technology and to support the mission to raise citizens who are aware of their responsibilities and have critical thinking skills.

Clear expectations and persistent approach of the French curriculums regarding the use of technology in education and inclusion of technology in national student assessment exams show that French educational system has a distinguished position with respect to the integration of technology in education. In this regard, a detailed study of the contents of this country’s curriculums and national exams is an appropriate example of the integration of technology in education, which can shed light on desirable changes or future studies at an institutional level.

The aim of this study is therefore to investigate the integration of the spreadsheet in mathematics education from an institutional perspective. The study will explore the position of the spreadsheet in the French mathematics curriculums and national assessment exams in secondary education general streams. This study will seek answers to the following questions:
- Which grade levels of the French secondary education general streams mathematics curriculums include the spreadsheet and what potentials of the spreadsheet are emphasized?
- Which epistemic and pragmatic values of the spreadsheet are emphasized in the French secondary education general streams mathematics curriculums; and is there an equilibrium between these values?
- How are the student outcomes covered in the curriculums assessed?

2. METHOD

Adopting the document analysis method, this study consists of two parts. In the first part, the subjects containing the use of the spreadsheet were determined first by examining the secondary school and high school mathematics curriculums and the accompaniments to the curriculums. After that, by means of content analysis, the pragmatic and epistemic values of the spreadsheet contained in these subjects were determined.

The second part of the study deals with the PTM and the EBEMIT exams, which assess the use of the spreadsheet. A corpus of these exams was analyzed in terms of the technological tools required and topics including the use of the spreadsheet. In addition, the expected outcomes related to the use of the spreadsheet in B2i assessment were discussed in this part.

3. SPREADSHEET IN FRENCH STANDARDS AND CURRICULUMS

In French education system, secondary education general streams consists of 4-year secondary school and 3-year high school education (Table 2). Secondary school grade levels are 6ème (11-12 age), 5ème (12-13 age), 4ème (13-14 age) and 3ème (age 14-15) and high school grade levels are 2nde (15-16 age), 1er (16-17 age) and Terminal (17-18 age). In high school, after 2nde, in 1er and Terminal grade levels, pupils are divided into three ‘streams’ or ‘series’ according to their interests and achievement status: Scientific (Sciences) (S), Economic and Social (Économique et Social) (ES), and Literary (Littéraire) (L) streams. A curriculum determined by the Department of National Education for each branch is implemented all around the country.

Table 2: French secondary education general streams system

<table>
<thead>
<tr>
<th>Age</th>
<th>Grade</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-12</td>
<td>Sixième</td>
<td>6ème</td>
</tr>
<tr>
<td>12-13</td>
<td>Cinquième</td>
<td>5ème</td>
</tr>
<tr>
<td>13-14</td>
<td>Quatrième</td>
<td>4ème</td>
</tr>
<tr>
<td>14-15</td>
<td>Troisième</td>
<td>3ème</td>
</tr>
</tbody>
</table>

Lycée Général\(^1\)

<table>
<thead>
<tr>
<th>Age</th>
<th>Grade</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-16</td>
<td>Seconde</td>
<td>2nde</td>
</tr>
<tr>
<td>16-17</td>
<td>Première (Sciences, Economique et Social, Littéraire)</td>
<td>1ère (S, ES et L)</td>
</tr>
<tr>
<td>17-18</td>
<td>Terminale (Sciences, Economique et Social, Littéraire)</td>
<td>Term (S, ES et L)</td>
</tr>
</tbody>
</table>

\(^1\) Lycées are divided into the lycée général, the lycée technologique and the lycée professionnel.

In this paper, lycée général is examined.
3.1. Secondary School Curriculum

The French secondary school level mathematics curriculum consists of four learning areas for all grade levels: data management and organization, numbers and calculation, geometry, and the quantities and measurements. The curriculum is based on the assumption that learning mathematics shouldn’t be built on only formal learning particularly in secondary school level and that a practice environment, like that of geometry, can be created with ICT support in other three areas as well so that the relevant concepts can be learnt more effectively.

In secondary school curriculum, the spreadsheet is covered in both technology course and in mathematics course. Also, the technology curriculums of 6eme and 5eme grade levels cover the use of some basic software such as word processor, e-mail, and browser. Students are expected to utilize these types of software by means of group work activities and these activities include the use of spreadsheets, too. Thus, a student beginning secondary school education starts to use spreadsheets beginning from the first year of secondary school. The spreadsheet is first presented in 5eme grade level in secondary school mathematics curriculum. The use of the spreadsheet is recommended in the statistics learning area for graphical (e.g. diagrams, distributions, histograms) and numerical (e.g. tables) representation of data. In addition, the curriculum assumes that, as a tool providing different learning environments other than paper and pencil, the spreadsheet offers enriched learning environments and help teachers save time. Therefore, with respect to this grade level, the curriculum seems to emphasize the pragmatic value of the spreadsheet on graph drawing.

Unlike 6eme and 5eme, 4eme grade level mathematics curriculum contains activities which involve the use of spreadsheets by students. In 4eme grade level, students are expected to create a worksheet, modify it, write formulas and construct graphs. In addition, the spreadsheet is presented in statistics and algebra areas. The statistics learning area involves calculating the mean of large numbers by spreadsheet (Appendix 1). Quite differently, the potential of the spreadsheet for teaching the concept of the function and algebra topics is considered to begin from this grade level on. According to the curriculum of this grade level, by modifying a cell in the spreadsheet, the variable can be expressed in different ways and the concept of the variable can be presented with various examples and a concrete approach. In 4eme, therefore, the spreadsheet emerges as a teaching tool used in mathematics lessons to teach the concept of the variable as well as for numerical and graphical representation of data and some calculations by students. According to an official text prepared in 2004 for 5eme ve 4eme grade levels, the spreadsheet can be effective in teaching algebra by means of study and construction of formula (p. 69) [24].

With respect to this grade level, the curriculum covers pragmatic values of the spreadsheet such as making mathematical operations on large numbers and
constructing graphs as well as its epistemic value for using formulas in the algebra learning area and introducing the concept of the variable.

The curriculum of 3ème grade level covers the use of the spreadsheet in algebra, statistics, arithmetic and introduction to the concept of the function. In this grade level, the spreadsheet is used to teach the concept of the variable by placing a set of values for a variable in the spreadsheet and manipulating algebraic expressions which use these values in the spreadsheet.

The concept of the function is introduced in this grade level and its presentation involves the use of the spreadsheet. When teaching students how to match one number to another, which is a feature of the concept of the function, they are shown that the spreadsheet makes it possible to obtain both the graphical and numerical matching meanings of the concept. In 3ème, the last grade level of secondary school education, the spreadsheet can be used in teaching integers and rational numbers, particularly for the algorithms for finding the greatest common divisor (Appendix 2). In this grade level, creating an algorithm is related to the pragmatic value of the spreadsheet and graphical and numerical study of the matching feature of the concepts of the variable and the function is related to the epistemic value of the spreadsheet.

According to the curriculums of 5ème and 3ème grade levels, pupils in these grade levels are expected to study more complex statistical subjects, which they cannot study in traditional environments, with help of the spreadsheet because it provides learners with an enriched learning environment. This shows that the pragmatic value of the spreadsheet is emphasized in the statistics learning area.

Figure 1: Spreadsheet in secondary school curriculum
Another point emphasized in the secondary school curriculum is individual studies by students. The secondary school level curriculum states that classroom activities should be followed by regular practice sessions in computer rooms so that students can use the spreadsheet themselves. The curriculums in the first two grades of secondary school education aim to equip students with skills to use the spreadsheet in technology courses while its possible use by students in mathematics classes is completely left to the discretion of mathematics teachers. Beginning from 4eme grade level, however, students are expected to use the spreadsheet in a way requiring active use of it in mathematics classes in learning the subjects of data analyses, statistics, arithmetic, and algebra and concepts related to the function (Figure 1).

Only the pragmatic values of the spreadsheet are emphasized in 5eme grade level. Similarly, the pragmatic values of the spreadsheet are emphasized more in 4eme and 3eme. However, in these grade levels, teaching the concepts related to algebra and analysis, which are new to students, involves the epistemic values of the spreadsheet, which suggests that the secondary school curriculum tries to establish the equilibrium between these two types of values.

3.2. High school Curriculum
In France, revision studies for high school curriculum began in 2010 and, after a gradual process of revision, the resulting new high school curriculum was launched in 2013. In this part of the study, the previous curriculum, which was implemented between 2001 and 2013, will be examined and then the changes brought about by the new curriculum will be discussed.

a) Mathematics Curriculum between 2001 and 2013
In 2nde, the first grade level of high school education, the curriculum emphasized the importance of the use of the spreadsheet in students’ algebraic expression of a given situation. Also, the importance of correlating the formulas to be written in the spreadsheet and algebraic formulas with the concept of the function was emphasized. According to this curriculum, students were expected to realize that, during these activities, performing each step to obtain the formula in separate columns if the function $f$ was given as a formula, facilitated understanding the whole set of steps that converts $x$ to $f(x)$. In addition, the graphical representation of functions through the spreadsheet was also among the subjects to be presented in all the grade levels (Appendix 3).

In 1er grade level, students chose among the three streams (i.e. S, ES, and L) with recommendation based on their interests and achievement status and took courses within these streams in the last two grade levels of high school. The mathematics curriculum of 1er S grade level consisted of three parts: analysis, geometry, and statistics and probability. The curriculum of 1er S emphasized simultaneous observation of the effect of the data variation on the results through the dynamic
environment provided by the spreadsheet. In the subject of the derivative, students were supposed to observe the margin of error that might occur in linear approximation on a known function in the spreadsheet environment. The curriculum of ES stream consisted of two parts: statistics and probability, and algebra-analysis. In 1ES, the spreadsheet was used in statistics and probability subjects, especially in examining chronological sequences (e.g. population change, bank accounts, etc.). The spreadsheet was important in determining the mean of these sequences and in observing the possible variation of these means on their graphical representation. The spreadsheet was used for sequence representation in algebra and analysis in both of the streams (i.e. 1er S and 1er ES). Here, the use of the spreadsheet was recommended in the calculation of the terms of sequences, comparison of the increases in arithmetic and geometric sequences and calculation of limit (Appendix 4).

On the other hand, 1er L stream took an approach different from those of S and ES streams. The main objective of the mathematics curriculum of this stream was to provide students with a basic mathematical culture by equipping them with the skills to think critically, to interpret the information and data obtained and to reformulate. For this purpose, the curriculum covered mathematics topics that are frequently encountered in daily life such as number tables, percentage calculations, some statistical parameters and graphical representation. The curriculum consisted of three parts: numerical information, statistics, and types of growth.

Each topic of this curriculum, which was introduced in 1999, was prepared considering the use of technology, especially the use of the spreadsheet, and the course was called “Mathematics and Information Technology”. Unlike the curriculums of the other streams, 1er L curriculum required a “systematic” use of the spreadsheet in mathematics activities during the whole academic year. The aim was to identify the mathematical outcomes from the spreadsheet covered in the earlier grades and put them into practice through the spreadsheet.

The curriculum of 1ere L introduced the spreadsheet in association with the outcomes of discovering the dynamism of an automatic calculation sheet and explaining the relationship between the different cells of this sheet in a “numerical information” learning area. After that, it included an activity written in everyday language to simply show the dynamic aspect of a sheet through the new changes to be made with new data on a new sheet. These activities, which were carried out at the beginning of each schooling year, aimed to let students remember the concepts of the variable and function presented in 2nd grade, practice using formulas, and become familiar with the use of the spreadsheet. With respect to the spreadsheet, at the end of this grade level, students were expected to write a simple formula, copy a formula or a cell, use relative or absolute address, use some available basic functions (e.g. max. m, n., sum, average, if, etc.) and construct graphs.

The statistics learning area required analysis of the tables with large values. The
use of the spreadsheet was particularly emphasized in relation to the subject of sequences and growth. The aim of the subject of sequences was to let students define, recognize and name the types of growth used for explaining some situations. Here, chronological sequences in media played an important role. The types of growth were introduced based on the arithmetic and geometric sequences. The importance of the spreadsheet was emphasized especially in studying the concept of the recurrence and studying linear and exponential growth graphically.

In the senior year of high school, in Ter S, the limits of functions and sequences were introduced through activities carried out with the spreadsheet in analysis. In addition, the use of “dichotomy” or “balayage” methods in the spreadsheet was required in the solution of the equations in the form of \( f(x) = k \) (Appendix 5). One of the objectives was to examine the convergence of sequences with (Un-L) limitation studies carried out in the spreadsheet. In Ter ES, the statistics area aimed to let students figure out the meaning of least squares through the calculations carried out in the spreadsheet. In the subject of sequences in the analysis learning area, the spreadsheet was used in understanding the formation of linear recursive sequences expressed as \( u_{n+2} = a \cdot u_{n+1} + b \cdot u_n \) and in calculating their terms (Appendix 6). In Ter L, especially the need for the use of students’ skills in the spreadsheet in mathematics courses was emphasized. The use of the spreadsheet was presented in creating algorithms, particularly in writing the Euclid division algorithm. In the analysis learning area, the use of the spreadsheet was regarded important in the completion of the concepts of arithmetic and geometric sequences, especially in experimental applications.

A common objective in all the grade levels of high school education was to study and develop algebraic, graphical and numerical operations together, which is the most important advantage offered by the spreadsheet.
With effect from 2001 until 2013, the high school curriculums for 1er ve Ter grade levels emphasized mainly pragmatic values of the spreadsheet such as calculation of the terms of a recursively defined sequence, the difference between two consecutive terms and the coefficient; simultaneous graphical representation of multiple sequences; simulation of different types of growth; easy setup and display of some classical algorithms; and so on. On the other hand, the epistemic values of the spreadsheet were emphasized more in 2nde grade level and the spreadsheet was used for formula writing and teaching the concept of the variable in teaching algebra, and providing graphical and numerical presentation of matching feature of the concept of the function. In 1er ve Ter grade levels, on the other hand, the epistemic value of the use of the spreadsheet was limited to the concept of the least squares in statistics and to comprehension of the concepts of the recurrence and limit in analysis area.

b) New Mathematics Curriculum (2013)

According to the new curriculum of 2nde grade level, the spreadsheet is used in the subject of the function again. However, the spreadsheet is now stated to be used for a graphical or algebraic approach in the solution of an optimization problem or the inequality \( f(x) > k \).

The mathematics course in L stream, which was compulsory in the previous curriculum, is now an elective course in the new curriculum and there is a common mathematics curriculum for L and ES streams. The curriculum of 1er grade level covers the use of the spreadsheet in defining fluctuation interval in the statistics area.
and in studying the sequences defined by a recursive relationship and solution of problems comparing variations in the analysis area in all the three streams. In the common ES/L curriculum, the spreadsheet is stated to help students learn especially the index notation while the curriculum of S states that the use of the spreadsheet can provide an experimental approach to the concept of limits. In all the three streams in Ter grade level, the limits of functions and sequences are introduced through the activities carried out in the spreadsheet in the analysis area. Also, in Ter ES/L, in the statistics area, the spreadsheet is used for obtaining a probability based on the normal distribution and simulating a survey.

A comparison of the former curriculum with the new curriculum shows that there aren’t any major changes in the topics covering the use of the spreadsheet for S and ES streams. On the other hand, there seems to be a complete change in the curriculum of 1ere L stream. While the previous curriculum covered the use of the spreadsheet in all the relevant topics, the use of the spreadsheet is limited to just a few topics in the new curriculum.

Unlike the previous curriculum, the new curriculum has no accompaniments, but there are some documents provided as resources under some topics. Neither the new curriculum itself nor its resource documents provide sufficient explanations regarding the use of technology. Therefore, in the new curriculum, the values related to the spreadsheet are limited to its pragmatic values such as constructing graphs and simulations and its epistemic values are not addressed at all.

However, another important point about the high school mathematics curriculum is the use of the algorithm. As a part of mathematics learning activities in all of the
grade levels, students are expected to learn organization of an algorithm (e.g. input-output control, assigning a value, and formatting calculation) and carry out algorithmic activities. According to the curriculum, these algorithms can be expressed in a natural and symbolic language and they can also be performed by using technological tools such as the spreadsheet.

4. ASSESSMENT OF STUDENTS’ SPREADSHEET SKILLS

4.1. Information Technology and Internet Proficiency Certificate (B2i)

B2i’s, which aim to assess students’ outcomes regarding the use of technology in the educational process from primary education to higher education, also cover the use of the spreadsheet. In this certificate assessment, knowledge, behavior and outcomes related to capacity are assessed by means of various sub-headings in the five areas (ability to adapt an information working environment for oneself; ability to adopt an inquiry behavior; ability to create, produce, manage and process data; ability to inform and file; and ability to communicate and exchange information). Assessment can be carried out by teachers from different subject areas. Each competence item in the “proficiency certificate” prepared for a student is accompanied by a signature and date showing a teacher’s approval (Appendix 7). This proficiency certificate does not signify an examination passed but instead an assessment of a process. Those students who prove successful in 80% of the items in the proficiency certificate exam are granted B2i certificate. This document is prepared in three levels: primary school (B2i-level1), secondary school (B2i-level2) and high school (B2i-Level3) levels.

Since the expected outcomes vary in each level of B2i’s, the outcomes that can be achieved with the use of the spreadsheet in mathematic lessons match the following outcomes that are expected as a part of B2i level 2 [25]:

<table>
<thead>
<tr>
<th>Outcome areas</th>
<th>Outcomes that can be assessed with the spreadsheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ability to adapt an information working environment for oneself</td>
<td>1.2) I can access a file or software in the working environment.</td>
</tr>
<tr>
<td>2. Ability to adopt an inquiry behavior</td>
<td>2.4) I investigate the results examined in information technology environment (e.g. calculation, graphs, corrector, etc.).</td>
</tr>
<tr>
<td>3. Ability to create, produce, manage and process data</td>
<td>3.3) I can collect multiple components in the same document (e.g. text, image, table, graphs, video, etc.).</td>
</tr>
<tr>
<td></td>
<td>3.4) I can create and modify a spreadsheet and insert a formula.</td>
</tr>
<tr>
<td></td>
<td>3.5) I can construct a graph a given type.</td>
</tr>
</tbody>
</table>

As can be seen in the table 3, the student outcomes assessed in secondary school level are the ability to create a sheet in the spreadsheet and the ability to use formulas and create graphs. Students are also expected to query the results presented by the spreadsheet.
4.2. Practical Test of Mathematics (PTM) in Ter S, 2nde and 3eme

In French public high school graduation (Baccalaureate) examinations, as Drijvers [17] states, the use of technology is allowed but students’ answers are not regarded valid unless the process performed with these tools is explained or demonstrated. There has been an effort to change this situation and grade students’ use of technology in problem solving process by means of a pilot study called “practical test of mathematics” administered to scientific stream students since 2005. This exam was later expanded and it was introduced in 3eme and 2nde grade levels.

The exam is administered in a computer room; questions require significant use of ICT (e.g. graphical calculators capable of programing, specialized computer software the spreadsheet, the plotter, dynamic geometry and computer algebra systems). A set of exam questions consisting of 20-25 questions is delivered to schools. Attached to the questions are a leaflet for teachers with explanations for each of the exam questions and an assessment sheet (Appendix 8). Students are asked questions chosen from the set by the school’s teachers. In accordance with the regulations of the ministry, the exam is administered as a one-hour individual exam in a computer room where each examiner controls a maximum of four students.

Depending on internet accessibility, a corpus of exams questions prepared by three academies (Versailles, Rouen and Strasbourg) was created with 115 questions for Ter S grade levels between the years 2005 and 2011 and 44 questions for 2nde, 93 questions for 3eme grade levels between years 2008-2011.

Analysis of the exam questions for Ter S grade level revealed that 27.8% of them addressed the use of the spreadsheet directly. On the other hand, graphing software could be used in 23% of the corpus. When the questions were analyzed according their topics, these exam questions were also evaluated considering the fact that the spreadsheet can be used in these questions as well. The use of the spreadsheet was covered by 36.4 % of the questions in 2nde and 36.6 % of the questions in 3eme grade levels (Table 4).

<table>
<thead>
<tr>
<th>ICT in PTM (%)</th>
<th>Geometry software</th>
<th>Spreadsheet</th>
<th>Grapher</th>
<th>Calculator</th>
<th>CAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ter S</td>
<td>48.7</td>
<td>27.8</td>
<td>23.4</td>
<td>6</td>
<td>5.2</td>
</tr>
<tr>
<td>2nde</td>
<td>63.6</td>
<td>36.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3eme</td>
<td>63.4</td>
<td>36.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

As can be seen in Table 5, the use of the spreadsheet is mainly required in the topics of analysis in Ter S. The questions assessed students’ basic skills such as creating a spreadsheet, writing a formula and constructing graphs.
Table 5. Spreadsheet in PTM subjects

<table>
<thead>
<tr>
<th></th>
<th>Analysis (Ter S)</th>
<th>Arithmetic (Ter S)</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functions</td>
<td>71.2</td>
<td>17</td>
<td>11.8</td>
</tr>
<tr>
<td>(2nde – 3eme)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ter S</td>
<td>71.2</td>
<td>17</td>
<td>11.8</td>
</tr>
<tr>
<td>2nde</td>
<td>37.5</td>
<td>43.75</td>
<td>18.75</td>
</tr>
<tr>
<td>3eme</td>
<td>38.2</td>
<td>50</td>
<td>11.8</td>
</tr>
</tbody>
</table>

Both 2nde and 3eme grade levels mainly included questions about numbers and calculations followed by those about the concept of the function (Appendix 9).

An official report was prepared for a general evaluation of PTM (Ter S) [30]. This report was based on the observation and exam results of more than 50,000 students from over 1000 high school and on a survey for teachers who were involved in PTM. According to this report, the students obtained high scores with an average of 13.9 out of 20 (Appendix 11). In the report, this result was interpreted as an indicator of students’ high-level ICT skills. It is also emphasized that the majority of teachers received training for the use of ICT (dynamic geometry software, spreadsheet and CAS) in many academies in France during the last 15 years. The majority of these teachers claimed that they had sufficient experience relating to the use of ICT and they expect that the necessary equipment be provided for a systematic use of ICT in the lessons. In the report, it is also underlined that PTM had a positive effect on the development of teachers’ practices.

4.3. Early Baccalaureate Exam of Mathematics and Information Technology (EBEMIT) in 1ere L (based on the 2001 curriculum)

Until the year 2013, EBEMIT was a part of the system as a distinct exam through which students’ knowledge of the use of the spreadsheet is assessed directly. When mathematics was made an elective course, this exam was last administered in 1ere L in 2013.

Between 2001 and 2013, Mathematics and Information Technology course was the last compulsory mathematics course taken in high school by students in 1ere L stream. For this reason, students sat the mathematics course exam, a part of the baccalaureate exam at the end of the senior year of high school, one year earlier. In line with the content of the course syllabus, this exam included questions assessing students’ knowledge of the use of the spreadsheet. However, this exam was not on computer. Students were given a sample spreadsheet or tables related to the exam question together with exam documents in paper exam.

Taking into account the exam questions in different examination centers, a total of 75 exam documents of this examination administered between the years 2001 and 2010 were analyzed and it was found that 64 exams contained a minimum of one
question related to the spreadsheet (Table 6).

Table 6: Spreadsheet in EBEMIT

<table>
<thead>
<tr>
<th>ICT in EBEMIT (%)</th>
<th>Spreadsheet in EBEMIT subjects (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreadsheet</td>
<td>Numerical information 19.1</td>
</tr>
<tr>
<td>No ICT</td>
<td>Statistics 14.7</td>
</tr>
<tr>
<td></td>
<td>Growth 66.2</td>
</tr>
</tbody>
</table>

According to the distribution of the exam questions in this corpus about the spreadsheet based on the subjects in 1ere L curriculum, approximately 66% of them were related to the subject of growth.

The questions about the spreadsheet included writing a formula to perform a given process or choosing one among proposed formulas and calculating and interpreting the change caused by copying the formula and the values in the specified cells (Appendix 10).

The main feature of the spreadsheet is that it allows for automatic updating of a sheet when performing operations with the help of formulas. This gives the spreadsheet a dynamic feature. The difference between a spreadsheet and a table lies the use of formulas. Writing and using formulas is one of the basic outcomes covered in the curriculums beginning from secondary school level. This competency was also assessed in EBEMIT.

On the other hand, although the curriculum emphasizes the potential of the spreadsheet to construct graphs and covers some statistical functions of it, this exam cannot be considered to effectively assess these uses of the spreadsheet since it is a paper-pencil test. A report published in 2007 [23] states that this exam is appropriate for the content of the curriculum, but a part of it should be taken in a computer room using a spreadsheet.

5. CONCLUSION

This study investigated the institutional perspectives for the integration of the spreadsheet in secondary school level mathematics education with respect to France. Both the relevant curriculums and national exams were analyzed in order to explore the institutional approach about this subject in France.

It is possible to suggest that, in mathematical sense, there is a systematic relationship among the topics from algebra towards analysis and an identifiable set of concepts (e.g. algebraic expression, variable, formula, equation, function, limits, etc.) [26]. This situation can be explained by the ecological relationships, a popular expression in French mathematics education, between these concepts, in other words
by the fact that these concepts feed on each other [27]. In parallel with the nature of the areas described above, research on secondary education mainly focuses on the potential of the spreadsheet for the subjects of algebra and functional relationship. This situation seems to apply to the French mathematics curriculum, too. When we consider the secondary school and high school curriculums as a whole, the French approach seems to follow a systematic strategy of the use of the spreadsheet from algebra to analysis. However, the study identified different uses in different grade levels for only the same subject (simulation and fluctuation) in the areas of statistics and probability. This difference about the strategies of use in these two areas could be due to the nature of these areas and research in the field of mathematics education.

This study also examined the equilibrium between epistemic and pragmatic values in this integration and discussed how these values emerged in French curriculums. Artigue [10] states that if we want make technology legitimate and mathematically useful, there should be “modes of integration allowing a reasonable balance between the pragmatic and the epistemic power” of the tools used. The French curriculums’ use of the spreadsheet mainly emphasizes its pragmatic values, but its epistemic values are covered as well, which could be regarded as an effort to establish the equilibrium suggested by Artigue. The previous curriculum of 1ere L, which was in effect between 2001 and 2012, regarded the use of the spreadsheet not just as a pedagogical support for paper-and-pencil activities, but it also tried to address the relevant subjects in line with the potential of the spreadsheet. However, the change in the mathematics teaching approach regarding this stream in the new curriculum, which was launched in 2013, could affect the use of the spreadsheet as well. On the other hand, although the curriculum launched in 2000s removed programming and information technology courses in parallel with changes in technological tools and software (e.g. moving objects on screen, making calculations with a single click, etc.) and regarded technology as a pedagogical and didactic tool with a tool-oriented approach, the new program launched in 2013 puts a special emphasis on algorithm. According to Artigue [9], this emphasis is an indication of the fact that the technology vision of the curriculum returned back towards the subject dimension. Considering the potential which the spreadsheet has for teaching and learning algorithm, the spreadsheet is likely to come into prominence in a different way with the new vision of the curriculum.

The strategies followed in the French curriculums are reflected in the practical exams with pilot studies assessing the outcomes prescribed in the curriculums. The exams of high school senior year mainly contain questions in analysis while the exams of the senior year of secondary school and first year of high school contain algebra questions. The study found that the learning area with the least number of questions about the use of the spreadsheet was the statistics area. The outcomes assessed in the practical exams, were limited to creating a sheet, writing formulas and constructing graphs. On the other hand, institutions’ inclusion of the
spreadsheet in their exams will make it necessary for all the practitioners in the system to take the steps towards the use of these tools regardless of their personal opinions on the use of technology and therefore contribute to the creation of an environment appropriate for the desired integration of these tools [11,30]. In this regard, the results obtained in this study can shed a light on the search of other institutions for an effective integration and provide insight for future studies. This study found that France pursued a determined approach to this integration in terms of curriculums and assessments and took important steps to ensure it. Understanding this commitment and the steps taken can encourage other countries’ institutions in the decision-making and implementation phases of their own integration processes.

On the other hand, curriculums and assessments are only one of many factors affecting integration. It is clear that curriculum revisions alone cannot be sufficient for a successful integration. In addition, major changes driven by a top-down process are not likely to yield successful results [9] and this insistent approach can bring about unexpected results for classroom practices [28]. In a study about integration of the spreadsheet in France with an instrumental approach, Haspekian [29] identifies a marginal use of the spreadsheet despite the persistent attitude in the curriculums and the significant increase in the quantity of pedagogical spreadsheet resources and student activities (e.g. textbooks, web sites or professional publications). Haspekian suggests that this situation can be due to the difficulty teachers have in changing their practices and the structure of the spreadsheet, which was not originally developed for educational purposes. This author also states that the existing resources cannot offer teachers the assistance they expect for.

As a result, it is essential that institutions act in a way that supports teachers about integration instead of following a top-down process. Considering the fact that the use of technology is not spontaneous process, teachers should be informed about the approach adopted in the curriculums and there should be reference resources and activities to train teachers about the relevant in-class practices (e.g. in-service trainings, seminars, workshops, etc.). In other words, there can be new perspectives for the solution of integration problem when institutions shift from a top-down to a bottom-up approach, where integration is supported by determining the requirements for an effective integration.

REFERENCES


APPENDICES

Appendix 1
(http://www.ac-paris.fr/portail/jcms/d_6221/statistiques-sur-les-licencies-sportifs-en-france)

Statistics on Sport Licenses in France.
Sources: INSEE and Ministry of Sports and Youth

Disciplinary competences covered with reference to the curriculum:
Reading crosstabs, sorting, selection.
Constructing a graph.
Calculating a percentage and mean.

Competences B2i
3.3) I can collect multiple components in the same document (e.g. texts, images, tables, graphs, ...).
3.4) I can create and modify a spreadsheet and insert a formula.
3.5) I can construct a graph of a given type.

Exercise 1. Number of the licensees in the sports federation between 2000 and 2006
1) Calculate the total number of licensees per year.
Which method did you choose to calculate these sums?
2) Select and copy 5 ball-sports (lowest in the sheet).
Make a pie chart of these sports (the names of sports to appear).
What comment can you make?
3) Calculate the difference of licensees between 2000 and 2005 for each sport.
What do you notice? What sport has the highest increase in number of licensees?
What sport has the largest decrease in number of licensees?
Make a graph showing changes in the number of licensees in these two sports.

Exercise 2. Number of the female among sports licensees in 2004
a) Calculate the total number of female licensees.
b) Calculate the percentage of female licensees for each sport, and then round these percentages to 2 digits after the decimal point.
c) What are the four sports that are practiced more by women than by men in 2004?
1. 2. 3. 4.
How did you find them? Highlight them in the table.
d) What are the four sports that are most practiced by women in 2004?
1. 2. 3. 4.
Are they the same sports as in question c.
How did you find them? Highlight them in the table.


### Licensees sportifs

<table>
<thead>
<tr>
<th>Year</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2001</td>
<td>2002</td>
<td>2003</td>
<td>2004</td>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **A**: Sport license
- **B**: License in France
- **C**: License in the Union
- **D**: License in the Community
- **E**: License in the European Union
- **F**: License in the Mediterranean Union
- **G**: License in the Americas
- **H**: License in the African Union
- **I**: License in the Asian Union
- **J**: License in the Oceanian Union
- **K**: License in the Polar Union

### Difference in license numbers between 2000 and 2005

<table>
<thead>
<tr>
<th>Year</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2001</td>
<td>2002</td>
<td>2003</td>
<td>2004</td>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Evolution in % (percentage explanatory positive)

<table>
<thead>
<tr>
<th>Year</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2001</td>
<td>2002</td>
<td>2003</td>
<td>2004</td>
<td>2005</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Total licensed by year in France

- 2008: 2,178,011
- 2009: 2,396,952
- 2010: 2,647,751
- 2011: 2,837,707
- 2012: 3,047,667
- 2013: 3,274,840
- 2014: 3,516,340
- 2015: 3,776,504

### Comparison pétanque and canoe

- F. de pétanque et jeu provençal
- F. de canoë-Kayak

### Année 2004

- **A**: Total number of licenses (in thousands)
- **B**: Number of licenses for men
- **C**: Number of licenses for women
- **D**: Percentage of women in licenses

#### Total licenses (in thousands TOU) 2004

<table>
<thead>
<tr>
<th>Sport</th>
<th>Total Licenses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Football</td>
<td>2,461,782</td>
</tr>
<tr>
<td>Basketball</td>
<td>1,265,931</td>
</tr>
<tr>
<td>Rugby</td>
<td>1,205,831</td>
</tr>
<tr>
<td>Basketball</td>
<td>2,155,402</td>
</tr>
<tr>
<td>Handball</td>
<td>251,754</td>
</tr>
<tr>
<td>Volleyball</td>
<td>437,496</td>
</tr>
<tr>
<td>Water polo</td>
<td>392,954</td>
</tr>
<tr>
<td>Canoe-Kayak</td>
<td>1,722,722</td>
</tr>
</tbody>
</table>

#### Evolution pétanque and canoe

- F. de pétanque et jeu provençal
- F. de canoë-Kayak

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Appendix 2

Euclidian algorithm on the spreadsheet

IT skills for B2i Secondary school
1.2) I can access software and documents available from my working space.
3.4) I can create and modify a spreadsheet and insert a formula.

GCD (Greatest common divisor) with Euclidian algorithm:
We want to calculate the GCD of 702 and 273 using a spreadsheet ('Excel' application is given below).
1. Prepare a calculation spreadsheet as shown. In A1 cell, we write the greater of the two numbers.
2. Information:
   - We utilize the formula =ENT(A2/B2) to calculate the quotient of the Euclidean division of 702 by 273, in cell C2,
   - The formula to obtain the remainder of Euclidean division is =MOD(A2;B2).
To calculate the remainder, this formula can be replaced with =A1-C1*B1.
3. Justify the formulas written in cells A3 and B3, and complete cells C3 and D3 with formulas to obtain the quotient and remainder. ……………………………
4. Select the cells from A3 to D3. To copy down these cells, drag the fill handle, which is a small black square.
Why do some cells display these #DIV/0!? ……………….
The GCD of 702 and 273 is... (... is the last remainder is non-zero)
Use this spreadsheet to determine:
GCD(1961;2173),
GCD(1789;1998),
GCD(19799978000;9800998911)
Complete

(Severity of the spreadsheet: the number written in a cell is smaller than 9 999 999 999 999 981.c)

Appendix 3

Prerequisite:
Basic use of the spreadsheet – Concept of the function – In “2nde”: second-order polynomial functions.
Objective: to solve an optimization problem:
• to use the spreadsheet in solution of an experimental problem
• to provide a functional explanation to the problem studied
• in “2nde”: to demonstrate a conjecture by studying the variation of a function
Session flow: in computer room:
• students complete the spreadsheet prepared by the teacher by using spreadsheet formulas,
• then students read the answer to the problem, which is proposed on the spreadsheet.
• 2nde: Students examine the variation of the function, which is defined for showing observed solution.
Max Chocolate

Student worksheet
Mr. Choco is the manager of a supermarket. He buys boxes of chocolates at a price of €5 a box from a factory. In his shop, he sells a box for €13.60. He has an average weekly sale of 3000 pieces.

1a) Calculate the weekly purchase cost of boxes and recipe of Mr. Choco.
b) Calculate the profits.

2) Mr. Choco performs a market research which shows that any decrease in the price of 10 cents increases the sale of 100 boxes per week. We want to help Mr. Choco fix the selling price of the box of chocolates to achieve maximum profit.
a) Calculate the profit made by Mr. Choco if the selling price of a box of chocolates is reduced by 10 cents.
b) Complete the table below

c) Open choco_tp.ods and then complete the spreadsheet using formulas to help Mr. Choco to obtain maximum profit.

3) We call \( x \) the number of reductions applied and call \( f \) the function of profit realized in association with \( x \).
Determine \( f(x) \) and write it as expanded and collapsed.

In “2nde”: 4) Study the variations of the function \( f \) and thus find the solution of the problem observed in the spreadsheet.

Appendix 4
(http://mathematiques.ac-bordeaux.fr/pedalyc/seqdocped/projets/sierpinski/triangles_sierpinski_prof_v2.htm)

Prerequisite:
Basic use of the spreadsheet. – Sequences defined by recurrence, geometric sequences. – Variations and limits of a sequence.

Objective: To use the spreadsheet to conjecture variations and limits of two sequences
To demonstrate the conjectures

Sequence operation:
Reflection phase for the whole class: presentation of the problem without student worksheet or a spreadsheet provided and asking questions about how to obtain the first terms of these sequences.
Expected answers or questions that can be asked of students:
In step 1 … triangle is added,
In step 2 … triangles are added,
In step 3 … triangles are added.
One can conjecture that:
In step \( n \), … triangles are added:
Then the teacher asks students to:
- calculate the area of the original triangle
- calculate, at a given stage, the perimeter of the colored triangle depending on the perimeter of the uncolored triangle;
- calculate, at a given stage, the area of the colored triangle depending on the area of non-colored triangle.

In computer room: With the provided worksheet and spreadsheet, students complete the picture and make conjectures. Proofs can be completed at home.

### Sierpinski Triangles

**Student worksheet:**

Consider an equilateral triangle of side 10 cm. At each step, we construct in each uncolored equilateral triangle an equilateral colored (black) triangle whose vertices are the midpoints of the sides. The following diagrams show the steps 1-3.

Note that \((p_n)\) and \((a_n)\) are the perimeter and area of the colored surface to step \(n\).

The objective is to study the direction of variation and the possible limits of the two sequences \((p_n)\) and \((a_n)\).

#### Part 1: Calculation of the terms of the sequences of \((p_n)\) and \((a_n)\):

Open the file and complete triangles_sierpinski.ods columns with formulas:
- Enter the number of steps in column A.
- In column B, calculate the number of colored triangles added in step \(n\).
- In column C, calculate the perimeter of a triangle added in step \(n\).
- In column D, calculate the perimeter of the colored surface added in step \(n\).
- In column E, calculate the perimeter of the colored surface in step \(n\).
- In column F, calculate the area of one of the colored triangles added in step \(n\).
- In column G, calculate the areas of the colored triangles added in step \(n\).
- In column H, calculate the total area colored in step \(n\).

#### Part 2: Conjectures on the direction of variation and the possible limits of the sequences \((p_n)\) and \((a_n)\):

- What can we conjecture about the meaning of variations of the sequence \((a_n)\)?
- What can we conjecture about the meaning of variations of the sequence \((p_n)\)?
- What is the perimeter of the colored surface in step 20?
- At what value of \(n\) is the perimeter of \(p_n\) greater than 100000 m?
- At what value of \(n\) is the perimeter of \(p_n\) greater than 4,000,000 m?
- Does the sequence \((p_n)\) have a limit?
- At what value of \(n\) is the area of the colored surface \(a_n\) situated in the interval \([43.29; \sqrt{3}]\)?
- At what value of \(n\) is the area of the colored surface \(a_n\) situated in the interval \([43.30; \sqrt{3}]\)?
- What can we conjecture about the limit of the sequence \((a_n)\)?

#### Part 3: Mathematization of the problem:

Note that \(b_n\) indicates the uncolored area in step \(n\).
1) Justify that \(b_{n+1} = \frac{3}{4}b_n\) for all \(n \geq 1\)
2) Derive the expression of \(b_n\) in terms of \(n\).
3) Derive the expression of \(a_n\) in terms of \(n\).
4) Study the direction of variation of the sequence \((a_n)\) and calculate the limit of the sequence \((a_n)\)
Appendix 5

(1)

Seeking approximate solution of an equation of the form \( f(x) = 0 \) by dichotomy (binary search algorithm).

**Situation and principles:** \( f \) is a function defined on the interval \( I \). It is known that sometimes the equation \( f(x) = 0 \) has one solution and this one solution can be estimated (e.g. by applying the intermediate value theorem) without being able to calculate the solution precisely. There are several algorithms to provide frames (more precise in each step) to this solution. One of these algorithms is the dichotomy. (In Greek dichotomy means "cut in halves"). The method will be presented here with an example.

**Statement:** Consider the equation \( \cos x = x \), where \( x \in [0, \pi] \). Let us define the \( f \) function on \([0, \pi]\) by \( f(x) = x - \cos x \). We should therefore solve the equation \( f(x) = 0 \) equation. Exercise 85 on page 62 shows that this equation has only one solution on \([0, \pi]\).

1. We set \( a_0 = 0 \) and \( b_0 = \pi \). We denote \( I_0 = [a_0, b_0] \).
   a) Calculate \( c_0 = (a_0 + b_0)/2 \) and then \( f(c_0) \). Determine if \( f(c_0) \) or \( f(c_0) \). Note that the chosen interval is \( I_1 = [a_1, b_1] \).
   b) First, calculate \( c_1 = (a_1 + b_1)/2 \), then calculate \( f(c_1) \). By following the steps in 1.a., deduce \( [a_2, b_2] \) interval, the amplitude of which is half of \( [a_1, b_1] \) interval, which belongs to \( [a, b] \).

2. Following the procedure in question 1.b., define \( a_n \), \( b_n \) and \( c_n \) sequences so that \( a_n \), \( b_n \) and \( c_n \) sequences so that \( [a_n, b_n] \) and \( c_n = (a_n + b_n)/2 \).

3. Prepare a sheet on a spreadsheet based on the following model:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>f</td>
<td>g</td>
<td>h</td>
<td>j</td>
</tr>
</tbody>
</table>

**Help on the Spreadsheet:**

You will be required to use IF function in the spreadsheet with the following syntax:

\[ = \text{IF} (\text{condition, display value if TRUE, display value if FALSE}) \]

Example: When we enter

\[ = \text{IF}(A1>1.5;2;3) \]

we obtain

\[ = \text{IF}(A2>1.5;2;3) \]

To adjust the display format of a number:

Select number(s) involved, click **Format, cells, numbers.** Then choose the appropriate format.

- Fill B4 and C4 cells. Enter the appropriate formulas in cells D4, E4, F4, G4 and H4.
- In cell B5: \( =\text{IF}(E4*G4<=0;B4;D4) \)
- What should you write in cell C5?

4. Working on paper:
   a) What conjectures can you state about the sequences \( a_n \) and \( b_n \)?
   b) Propose a proof validating these conjectures.
Appendix 6

Sequences and the Spreadsheet

This exercise has two objectives:

About Mathematics: to develop an awareness of the effect of the first term of a recursive sequence.

About ICT: to continue to learn to use of the spreadsheet.

Part 1: Observations

The sequence \( u \) is defined by \( u_0=1, \ u_{n+1} = \frac{1}{3} u_n + 10 \)

1) Using a spreadsheet, calculate the first twenty terms of this sequence.
2) Then conjecture the direction of variation and the limit of this sequence.

SAVE YOUR WORK in your personal space.

3) We will now change the value of the first term \( u_0 \), for example, \( u_0 = 30 \), retaining the recursion formula.

Procedure:
- In order not to lose information, you can insert a column for values of \( n \) (it will serve for the graph later).
- Enter the value 30 in cell C1,
- Select the range of formulas B2: B20,
- Copy the formulas to the right, with the fill handle in the corner at the bottom right of the selected part.

Your conjectures about the behavior of the new sequence, are they the same?

4) Proceeding in the same way, make several successive attempts (6 or 7 in addition to the two already made) only by changing the value of the first term \( u_0 \) while retaining the same recursion formula.

5) Make a graph (scatter plot) representing these sequences.

Procedure:
Select the range of cells containing all the values and then use the Chart Wizard.

6) Look at the graph.

7) List three values such that the sequence \( u_0 \) is strictly increasing, three values such that the sequence \( u \) is strictly decreasing and one value such that the sequence \( u \) is constant.

What can be said about the limit of the sequence in each case?

8) Take the time to realize that the sequence \( u \) always seems monotonous, and that, moreover, it depends only on the value of \( u_0 \) (the recursion formula is always the same).

In which interval of \( u_0 \) does the sequence seem to strictly increasing or strictly decreasing?

Part 2

1) We will modify the spreadsheet to be able to calculate the values of the terms of the sequence \( u \) defined by its first term \( u_0 \); we can change the recurrence formula \( u_{n+1}=au_n+b \), and \( a \) and \( b \) can be changed. Notice that \( u_0=10 \). In cell E3 enter the formula to calculate \( u_1 \). Repeat copying for calculating \( u_2 \) and \( u_3 \) on cells E4 and E5 respectively. Draw this formula down to calculate \( u_2 \) in cell E4, \( u_3 \) on cell E5 etc.

2) Make a graph showing the sequence, \( n \) on the abscissa and \( u_n \) on the ordinate. 3) Change the value of \( a \). Look at the graph updated. 4) Notice the behavior, especially the convergence, of the sequence depending on the values of \( a \). Make conjectures related to the values of \( a \) and the convergence of the sequence.
Appendix 8

Simulation of drawing balls from an urn

Student’s and Teacher’s Sheet

Statement
We have two urns, one U shaped and one V shaped, containing balls that feel identical when touched. The U urn contains balls numbered from 1 to 10. The V urn contains ten balls numbered from 0 to 9. A game is played as follows: the player makes an initial bet of 100 tokens, then randomly draws a ball from the U urn and a ball from the V urn independently. For each ball bearing a number lower or equal to 4, the player receives $a$ coins ($a$ is a nonzero integer) but neither gains nor loses any tokens for drawing another ball. At the end of this game, we will look at the algebraic gain (gain or loss) counted in tokens.

Part A
1. We simulate 1000 executions of the game on a spreadsheet. First, we assume $a=150$.
   a) Make a spreadsheet based on the following model.
The examiner will help the candidate perform the test to calculate the algebraic gain.

b) Determine the average of the gains obtained during this simulation.
c) Using other simulations, conjecture the value which seems to reach the average of the gains.

The examiner will check which menu that allows repeating the same operation the candidate can use.

2. We wish to vary the value of $a$.
a) Adapt the worksheet to obtain the simulations depending on $a$.

The examiner will help the candidate having difficulty in editing his or her sheet.

b) Is it possible to give an $a$ value that seems to make the game fair?

Part B

3. Let $X$ be the random variable giving the algebraic gain after a draw.
a) Determine the expectation of $X$ depending on $a$.

If the candidate doesn’t know how to start calculating the expected value, the examiner will offer the candidate to investigate the probability of 3 cases depending on $a$.

b) Is it possible to find an $a$ to make the game fair?

Remind the definition of “fair game” if necessary.

c) Compare the result with the conjectures obtained in Part A.

Requested production:
- Visualization of the spreadsheet on the screen.
- Proven answers to the questions in 3.(a), 3.(b) and 3.(c).

Outcomes Assessed
- Using the test menus of a spreadsheet and calculator.
- Changing the value of a cell of a spreadsheet to test a hypothesis.
- Simulating a random experience with the spreadsheet.
- Calculating the expected value of a random variable.

Additional explanations on the Teacher’s sheet
Simulation of drawing balls from an urn

Each of the abilities does not have to be assessed. The final score will be determined based on the rubrics below and the candidate’s overall performance.
- Capacity to be tested (i.e., performance in using the tools and competency in proposing conjecture to be considered) equals to third-fourths of the main score.
- Capacity to assess the outcomes following this application equals to the remaining one-fourths of the main score.
- Capacity to take the initiative and benefit from the conversations with the examiner will be subjected to overall assessment.

An ability does not have to be fully mastered in order to be regarded as gained. The examples given below are not free from error.

### Abilities to Be Assessed

<table>
<thead>
<tr>
<th>Abilities to Be Assessed</th>
<th>The factors allowing to grade the student (to be filled out by the teacher)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student can use spreadsheets with a possible help for a simulation which includes integers between 1 and 10 (between 0 and 9) and for algebraic gain calculation by utilizing IF() function. The student benefits from verbal warnings.</td>
<td></td>
</tr>
<tr>
<td>The student can make conjectures on the obtained results. For example, the student utilizes possible verbal warnings to obtain other simulations depending on $a$.</td>
<td></td>
</tr>
<tr>
<td>The student exhibits some of his or her knowledge about the subject and his or her ability to do math: calculation of probabilities or expected value calculations.</td>
<td></td>
</tr>
<tr>
<td>The student proposes a correct solution way for the exercise by utilizing observed results: inquiring the expected values (espérance) to make $a$ 0 and comparing them with the conjectures obtained.</td>
<td></td>
</tr>
</tbody>
</table>

### Other observations:…………………………………..

### Appendix 9

[hypertext link](http://maths.spip.ac-rouen.fr/spip.php?article271)

Académie De Rouen 2008_2009 Academic Year / Applied Mathematics Exam in 3ème Grade Level

**Inequality**

**Problem:** A ski center proposes the tariffs below.

- **Tariff 1:** 20 € daily
- **Tariff 2:** 63 € for registration and then 5 € daily

The objective of this exercise is to determine after how many days choosing Tariff 2 becomes more profitable.

**Experimental Task**

1. Using the spreadsheet, calculate the prices for all days between 0th and 15th days for each of the options.

   ![Call your teacher to show the formulas and obtained values.]

2. After how many days does Tariff 2 become more profitable?

   ![Call your teacher to show your answer]

**Proof:** How can you confirm the results you observe in Question 2?

**Requested Products:**
- One or two tables created with the spreadsheet
- Answer to question 2
- Proposing the key steps of the proof
Appendix 10

Exercise 1.

PART 1.

In 2008, a TV channel, Media3 wishes to compete with the “20 o’clock News” of other two TV channels: Tele1 and Canal2. The management of Media3 decides to air a TV series called “The Dream Life” at 20 o’clock beginning from September 1, 2008.

In this exercise, the term “audience” means the average number of viewers per night, expressed in millions.

The 20 o’clock news audience of Tele1 and Canal2 channels are stable: 6.5 million people watch Tele1 and 4.9 people watch Canal2.

In September 2008, the number of the audience of “The Dream Life” is 3.4 million viewers, and it increases every month by 185000 viewers, that is 0.185 million viewers.

1) Justify that \( u_1 = 3.585 \).
2) What is the rule of \( u_n \) sequence? Express \( u_n \) in terms of \( n \).
3) The terms of \( u_n \) sequence are given in Table 1 in Annex 1, taken from an automatic calculation sheet.

In Table 1 in Annex 1,

a) In cell C3 write a formula to obtain the values of \( u_n \) by copying down. Among the proposals below, write all those that are appropriate (no justification is required):
   \[ =C2+D1 \quad =C2+0.185 \quad =C2+E1 \quad =C2+E1 \quad =C2+E1 \]
   b) Under these conditions, from which month on does the audience of “The Dream Life” surpass the 20 o’clock news audience of Canal2? Justify your answer.

PART 2.

Starting from September, 2009, the audience of the series does not progress in the same way. \( v_n \) indicates the number of viewers of “The Dream Life” in the \( n \)th month after September 2009.

Table 2 in Annex 1 gives the values of \( v_0 \) to \( v_5 \).

1. In Table 2 in Annex 1, the formula \( =C3/C2 \) is written in cell D3 and then the formula is copied down until C7. What is the formula written in D6?
2. In Annex 1, complete cells D3 to D7 in Table 2 by the numerical values (round the results to the nearest hundredth).
3. Determine the rule of \( v_n \) sequence for \( n \) values varying from 0 to 5
4. If the audience of this series continues to grow in this way, determine the month in which it exceeds that of the newscast of Tele1.
5. Calculate the percentage change in the audience of the series from September 2008 to February 2010 (round the result to 0.1%).

<table>
<thead>
<tr>
<th>Mois</th>
<th>( n )</th>
<th>( u_n )</th>
<th>Accroissement : 0,185</th>
</tr>
</thead>
<tbody>
<tr>
<td>septembre 2008</td>
<td>0</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>octobre 2008</td>
<td>1</td>
<td>3.585</td>
<td></td>
</tr>
<tr>
<td>novembre 2008</td>
<td>2</td>
<td>3.77</td>
<td></td>
</tr>
<tr>
<td>décembre 2008</td>
<td>3</td>
<td>3.955</td>
<td></td>
</tr>
<tr>
<td>janvier 2009</td>
<td>4</td>
<td>4.14</td>
<td></td>
</tr>
<tr>
<td>février 2009</td>
<td>5</td>
<td>4.325</td>
<td></td>
</tr>
<tr>
<td>mars 2009</td>
<td>6</td>
<td>4.51</td>
<td></td>
</tr>
<tr>
<td>avril 2009</td>
<td>7</td>
<td>4.70</td>
<td></td>
</tr>
<tr>
<td>mai 2009</td>
<td>8</td>
<td>4.89</td>
<td></td>
</tr>
<tr>
<td>juin 2009</td>
<td>9</td>
<td>5.07</td>
<td></td>
</tr>
<tr>
<td>juillet 2009</td>
<td>10</td>
<td>5.26</td>
<td></td>
</tr>
<tr>
<td>août 2009</td>
<td>11</td>
<td>5.45</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mois</th>
<th>( n )</th>
<th>( u_n )</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>septembre 2009</td>
<td>0</td>
<td>5,62</td>
<td></td>
</tr>
<tr>
<td>octobre 2009</td>
<td>1</td>
<td>5,732</td>
<td></td>
</tr>
<tr>
<td>novembre 2009</td>
<td>2</td>
<td>5,847</td>
<td></td>
</tr>
<tr>
<td>décembre 2009</td>
<td>3</td>
<td>5,964</td>
<td></td>
</tr>
<tr>
<td>janvier 2010</td>
<td>4</td>
<td>6,0833</td>
<td></td>
</tr>
<tr>
<td>février 2010</td>
<td>5</td>
<td>6,2049</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 11

![Graph 1: Nombre de candidats par sujet](image1.png)

![Graph 2: Répartition des notes par sujet](image2.png)