Teaching Chemistry and Physics in France: a brief overview

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After a summary presentation of the French educational system, this report describes and analyses recent developments in the teaching of Chemistry and Physics in France, in secondary schools (Collèges and Lycées). It also lists new educational uses by teachers and the ensuing feedback. Prepared for the SAT Project (ERASMUS+ project no: 2015-1-PLO1-KA201-016801)

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1 The French educational system

1.1 Brief history (1, 2015)

In France, the educational system is based on 5 main principles inspired by the French Revolution of 1789 and the different laws voted in the 19th and 20th centuries.

The institution of the Fifth Republic on 4 October 1958 specifies that it is "the duty of the State to provide free, mandatory, secular public education on all levels."

These 5 principles are:

- **Freedom of education**

  In France, public service education coexists with private establishments, subject to State control and entitled to State help (through contracts signed with the State).

  Nonetheless, the State alone is authorised to deliver University degrees; thus, degrees granted by private institutions have no official value unless they are recognised by the State. Examinations are regulated on a national level.

- **Free education**

  The principle of free public Primary School was established by the end of the 19th century by the Law of 16 June 1881. Free education was extended to secondary schools by the Law of 31 May 1933. Teaching in all public schools and establishments is free.

  School manuals are free until 3ème (end of cycle 4) along with the materials and supplies for collective purposes. In *Lycées*, manuals are usually paid for by families.

- **Neutrality**

  Public education is neutral: philosophical and political neutrality must be respected by teachers and students.

- **Secularism**

  The principle of religious secularism is one of the foundations of the French educational system since the end of the 19th century. Public education has been secular since the laws of 28 March 1882 and 30 October 1886. They institute the obligation of instruction and secularism of staff and programmes. The importance of secularism in republican school values was intensified by the law of 9 December 1905 instituting State secularism.

  Respect for the beliefs of students and their parents implies:

  - absence of religious instruction in programmes;
  - secularism of staff;
  - banning proselytism.

  Historically, religious freedom led to instituting one day free per week to leave time for religious instruction outside school.

- **Mandatory education**

  Since the Jules Ferry law of 28 March 1882, **education is mandatory**.

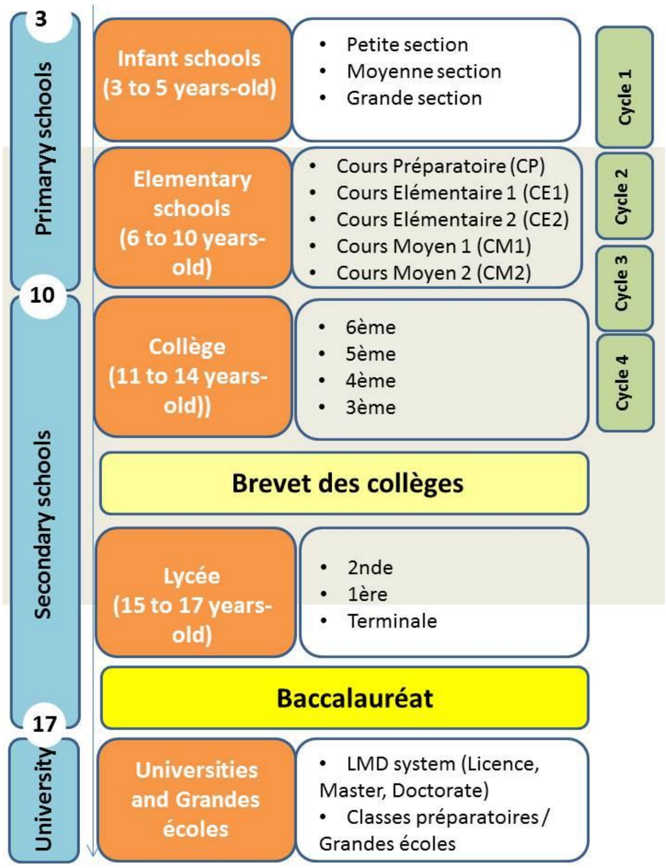
This obligation applies to all children age 6 and up, French and foreign, residing in France.
At first, education was mandatory up to age 13, then 14 starting with the law of 9 August 1936. Since Edict no. 59-45 of 6 January 1959, it was extended to age 16.

Family have two possibilities:

- Putting their children in a public or private school;
- Providing for their children's education themselves (with prior declaration).

1.2 School levels and establishments

In France, schooling is organised on two levels: Primary and Secondary, the latter leading to the Baccalauréat, provided by four types of establishments up to the Baccalauréat: Kindergarten (Infant school), Elementary school, *Collège* and *Lycée*.



From Kindergarten to the end of *Collège*, teaching is divided into four "cycles." This organisation shall be effective starting in September 2016):

- Cycle 1: Kindergarten
- Cycle 2 (basic learning skills): CP, CE1, CE2
- Cycle 3 (consolidation of learning): CM1, CM2 6ème
- Cycle 4 (development of learning): 5ème, 4ème, 3ème.

Teaching is structured coherently in each of these cycles.

These cycles also affect passage of students to the next class up: while parents can refuse to have their children left back within a given cycle (from CM2 to 6ème for example), this is not possible between cycles (6ème to 5ème, for example).

1.2.1 *Collège* (2, 2016)

At the end of Primary School, all students are admitted to *Collège* with no entrance exam. Thus, everyone can attend school in a single framework.

In France, the decentralisation laws place the construction and maintenance of *Collège*s under the responsibility of local communities, since they depend by law on the Départements.

Collèges cover a four-year curriculum: 6ème, 5ème, 4ème and 3ème. They are structured in two 2 cycles, as indicated above (1.2).

1.2.1.1 Cycle 3 (6ème, after CM1 & CM2)

Teaching in 6ème is complementary to that of CM1 and CM2. Thus, this new Cycle 3 promotes continuity in teaching between Primary School and *Collège*, which is a major and often difficult transition for students: they are in a new establishment; they have several different teachers (instead of a single one in Primary School); they change classrooms according to subject, etc.

1.2.1.2 Cycle 4 (5ème, 4ème, 3ème)

Cycle 4 is intended to confirm what has been taught and develop crosscutting teaching, in particular thanks to specific hours dedicated to EPI (Interdisciplinary practical teaching).

At the end of 3ème, students take an exam to obtain the DNB (Diplôme National du Brevet), which validates Core knowledge, skills and culture (see 2.1) to move on to:

- 2nde in a General and Technological *Lycée;*
- 2nde in a Vocational *Lycée* or the first year of preparation for the CAP (Certificat d'Aptitude Professionnelle) in a Vocational *Lycée.*

The DNB is not mandatory for continuing schooling past 3ème.

1.2.1.3 Subjects taught in Collège

The subjects taught in *Collège* are organised in disciplines:

- French
- Mathematics
- History-Geography
- Civics
- Modern Languages
- Life & Earth sciences
- Technology
- Visual Arts
- Musical Education
- Physical Education and Sport

- Chemistry and Physics

The four scientific disciplines, Mathematics, Chemistry and Physics, Life and Earth Sciences and Technology, are taught by four different teachers.

Art History and Information Technology are also part of the standard curriculum throughout *Collège*.

The objectives are set by national programmes to extend beyond the knowledge and skills of the Core programme (see 2.1).

1.2.1.4 Support measures

Educational support and, in 6ème, personalised support are available to *Collège* students as a complement to mandatory subjects. This support system promotes all students' success in school.

Thanks to educational support, students can stay in school after hours to receive help in doing their homework and learning their lessons and modern languages, as well as cultural and artistic activities or sports.

These systems, originally intended for students in the greatest difficulty and optionally, are now mandatory for all students to promote a system with less staff and on crosscutting themes.

1.2.2 *Lycée* (3, 2015)

After *Collège*, students can pursue their schooling in a General and Technological *Lycée* or a Vocational *Lycée*, with a three-year programme: 2nde, 1ère and Terminale.

In France, the decentralisation laws place the construction and maintenance of *Lycée*s under the responsibility of local communities, since they depend on the Regions.

Lycées prepare their own *projets d'établissement* (school projects), so each establishment can adapt its educational policy to its student body.

Programmes are defined on a national level.

1.2.2.1 General and Technological Lycées

General and Technological *Lycées* include three years. The first is a General and Technological 2nde common to all students wishing to pursue General or Technological studies, the choice between these two curricula being made at the end of this class. The classes of 1ère and Terminale in the different series lead to the Baccalauréat examination.

The Baccalauréat recognises the knowledge and skills obtained at the end of secondary school and marks the first level of Higher Learning. Consequently, it is the gateway to Higher Education.

1.2.2.2 Organisation of the General and Technological Baccalauréat

General Education

General Education leading to the General Baccalauréat comprises three series: Economic (ES), Literary (L) and Scientific (S).

It opens the way to Higher Education, mainly in Universities, preparatory classes for the Grandes Écoles or specialised schools.

Technological Education

Technological Education prepares for Higher Learning in Technology, mainly in STS (Science, Technology, Health) or a two-year programme in an IUT (University Institute of Technology), by pursuing training for a vocational degree (*licence*) or and an engineering degree.

The Technology Baccalauréat includes eight series:

- STL: Laboratory Science & Technology
- STI2D: Science & Technology of Industry & Sustainable Development
- STD2A: Science & Technology of Design and Applied Arts
- STMG: Science & Technology of Management
- ST2S: Science & Technology of Health and Social Work
- TMD: Techniques of Music & Dance
- Tourism and the Hotel Business
- STAV: Science & Technology of Agronomy and the Living, prepared in *Lycée*s under the aegis of the Ministry of Agriculture

1.2.2.3 Vocational Lycées

In Vocational *Lycées*, technological and vocational teaching represents 40% to 60% of students' curriculum, in the classroom and, depending on the speciality, in workshops, laboratories or construction sites. General subjects remain important: French, Mathematics, History-Geography, Science and English. Vocational *Lycées* prepare their students to receive a vocational degree either to enter the job market or to pursue their studies. These degrees include the Bac Pro (Vocational Baccalauréat with 75 specialities), CAP (Certificat d'Aptitude Professionnelle) and BEP (Brevet d'Études Professionnelles).

Apprenticeship is also growing in CFAs (Apprenticeship Centres), often close to Vocational *Lycée*s providing students with both practical courses and practical training, so they can enter the labour market as quickly as possible.

1.3 Teachers' working conditions (*Collèges* and *Lycées*)

1.3.1 Teaching load

There are two competitive exams to select *Collège* and *Lycée* teachers:

- approximately 75% of teachers have a CAPES (certification) degree and must teach 18 hours weekly;
- approximately 15% of teachers are *Agrégés* and teach 15 hours weekly. Having successfully passed the high-level competitive Agrégation examination, they are oriented towards *Lycée*s preparatory classes for the Grandes Écoles.

Teachers work for a total of 36 weeks a year (18 or 15 hours weekly, which leaves time to prepare their courses and for marking), plus one week on a jury for exams, and 15 weeks of holidays.

1.3.2 Workplace

Teachers are not required to remain in their establishments before or after their classes. They work most of the time at home. They have access nonetheless to offices they share in their establishments, usually not isolated in the teachers’ room.

1.3.3 Material and equipment

1.3.3.1 Personal equipment

Teachers have no personal office in their establishments, nor are they provided with computers or printers.

1.3.3.2 Experimental material

Collège and *Lycée* establishments are equipped with laboratories. There is one laboratory in each *college*, usually run by the teachers. In *Lycée*s, two laboratories coexist (one for Physics, the other for Chemistry), managed by laboratory staff: technicians, laboratory agents.

Experimental educational material, furniture, IT network, buildings are funded by:

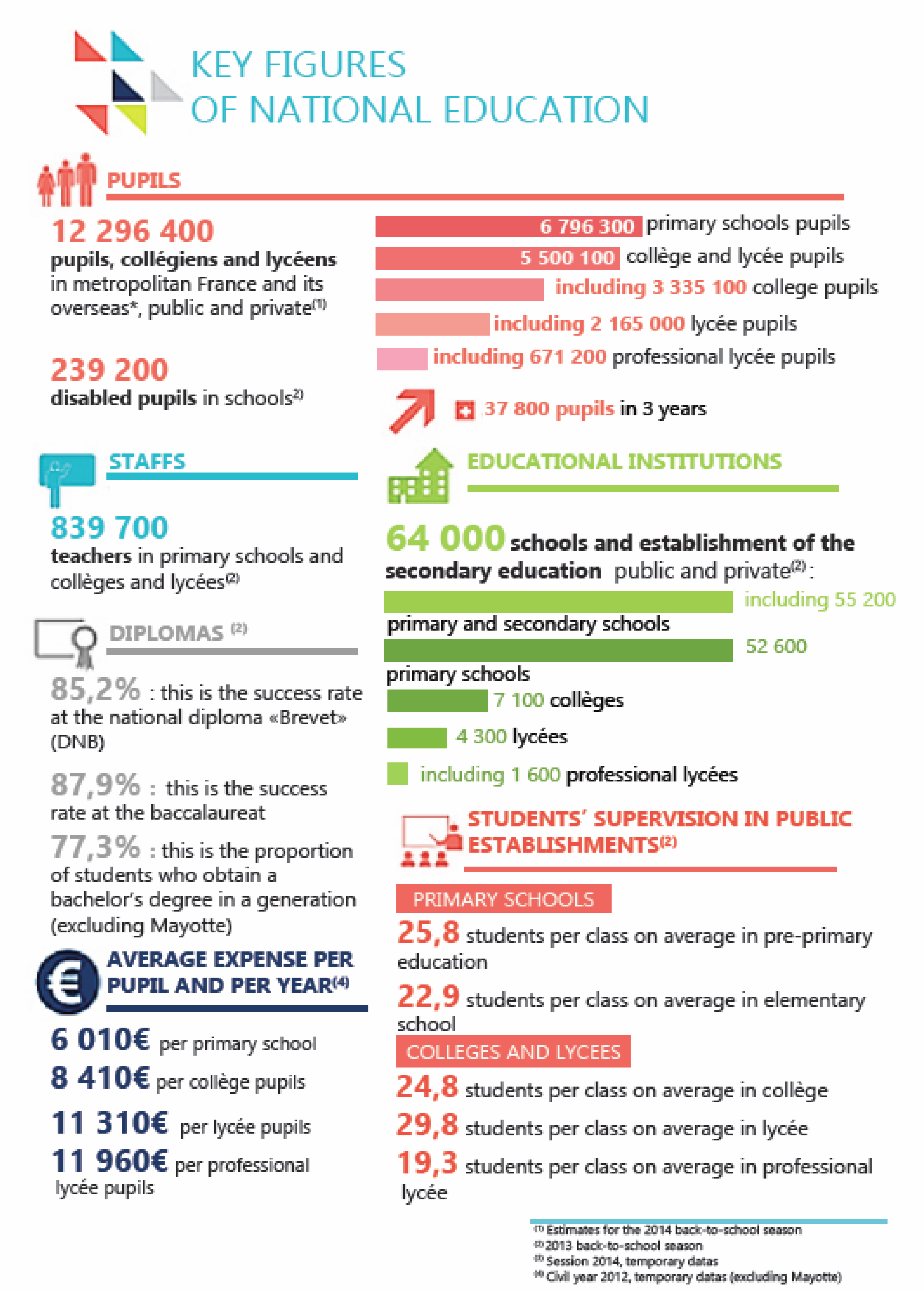
- the Regions for *Lycée*s;
- the Départements for *Collège*s.

1.3.3.3 IT network

Each establishment has an IT network. Each class has a computer connected to the network for the teacher. Some classes are equipped with computers for the students or “mobile classrooms” with laptops.

Moreover, all establishments have a dedicated ENT (Environnement Numérique de Travail) website for communicating, taking attendance, managing homework using digital notepads, storing information, creating blogs, exchanging, remote evaluation, sharing messages with students, parents and colleagues, displaying marks and averages, etc.

1.4 Key figures (4, 2014)



2 Teaching Physics in France

2.1 Core knowledge, skills and culture (5, 2016)

The “Core knowledge, skills and culture” programme concerns students age 6 to 16. It identifies the essential knowledge and skills they must have acquired through mandatory schooling at the end of *Collège*. Developed in 2005, it was updated in 2015 to become effective in 2016. This text is the reference for preparing programmes in different subjects taught in *Collège*, including Physics. This text also greatly influences programmes in *Lycées*.

This “Core” comprises five major fields:

- **1 - Language for thinking and communicating**

  Understanding and expressing oneself with four types of language:

  - French;
  - Modern foreign or regional languages;
  - Mathematical, scientific and IT language;
  - Artistic and body language.

- **2 - Tools and methods for Learning**

  Learning to learn, alone or collectively, in class or outside:

  - Access to information and communication;
  - Digital tools;
  - Organising individual and collective projects;
  - Organising learning.

- **3 - Personal and civic training**

  Transmitting basic values and the principles laid out in the Constitution:

  - Learning how to live in society, collective action and citizenship;
  - Moral and civic training;
  - Respect for personal choices and individual responsibility.

- **4 - Natural systems and technical systems**

  Giving students the basics of mathematical, scientific and technological culture:

  - Scientific and technical approach to the Earth and the Universe;
  - Curiosity and sense of observation;
  - Problem-solving capability.

- **5 - Representation of the world and human activity**

  Developing awareness of geographic space and historical timescales:
  - Understanding societies in time and space;
  - Interpreting human cultural production;
  - Knowledge of the contemporary social world.

This Core must be validated at the end of 3ème by teaching staff, although this is not determinant for future orientation. Starting in 2017, students receive the DNB on the basis of their marks in the examination and their proficiency in Core disciplines.

Studying Chemistry and Physics helps develop many Core skills, problem solving in particular (Core field 4). It is also expected to provide students with scientific and technical culture, to help them understand the world and contemporary society and participate actively in its development.

2.2 Recent developments in the teaching of Chemistry and Physics in France (2005-2015)

In the past ten years, teaching Chemistry and Physics has developed through educational reforms implemented by the Ministry of National Education. Without completely revolutionising programmes, these reforms introduced new practices aiming to help students acquire Core skills.

2.2.1 In *Collège*

2.2.1.1 The reform of 2005: the investigative approach

Until the start of the 21st century, educational programmes in Physics listed different disciplinary content (electricity, changes of state, electromagnetic spectra, etc.) without actually specifying the associated didactic approaches. For the first time, the reform of *Collège*s launched in 2005 included the investigative approach (IBSE: Inquiry-Based Science Education) for scientific disciplines. This change was perfectly consistent with the context of Core knowledge and skills (first version, 2006) defined at the same time, highlighting the development of students' skills.

In France, Physics was taught historically as an experimental science, but the experiments students performed followed a protocol drawn up in advance and imposed by teachers, leaving students very little autonomy. The investigative approach was clearly defined for the first time in the programmes, inciting teachers to implement it seriously in the framework of experimental activities:

- Choice by the teacher of an initial situation;
- Formulation of the problem (with or without guidance of students by the teacher);
- Formulation of hypotheses and design of the investigation to be undertaken (by the students);
- Investigation conducted by the students;

- Acquisition and structuring of knowledge.

These changes were accompanied by a new form of evaluation of students' work. From then on, teachers were expected to evaluate students' ability to complete steps in this experimental approach (written formulation of hypotheses, management of written traces of an experimental result). Evaluation grids were developed to help teachers in this new practice.

This methodological aspect was not imposed, however, as central to the programmes.

At the same time, teachers were asked to provide incentives to interdisciplinary work in the framework of projects, in particular through "themes of convergence," multidisciplinary themes — energy, health, meteorology and climatology, etc. — thereby bringing together several different disciplines: Mathematics, Chemistry and Physics, Life and Earth Sciences, Technology).

2.2.1.2 Feedback

Implementing the investigative approach encouraged teachers to reflect on educational practices in the classroom. While maintaining the experimental dimension essential to the discipline and to which teachers were strongly attached, more time was to be dedicated to designing experiments and analysing results. This strategy led teachers to think about the skills students develop and facilitate the acquisition of Core knowledge and skills published a year later. These two successive reformulations of the programmes led to better backing the skills acquired in the classroom with Core skills.

The two key formative characteristics of the disciplines of Chemistry and Physics remain:

- a strong experimental component;
- activating strategies to incite students to perform complex tasks and use investigative approaches to improve students' reasoning capacity and diversify the skills developed, independence and initiative in particular.

The results obtained in PISA surveys showed that French students did quite well in simple tasks, but had difficulty in performing "complex" tasks comprising several unspecified simple tasks.

Over the past ten years, educational strategies have changed and a major effort has been made for students to take a more active role in learning (even though it is important to remain vigilant to be certain that students' activities actually lead to performing intellectual activities). During this period, many resources concerning the investigative approach and "complex tasks," disciplinary and interdisciplinary, were published to provide support for teachers, especially on the Ministry of National Education's different websites, including the EDUSCOL reference site http://eduscol.education.fr/.

Clearly, such multidisciplinary "themes of convergence" have hardly been applied since 2005 and seem at present to have been dropped. Teachers' attention focuses, first on the investigative approach, then on evaluation of students during complex tasks. Never have themes of convergence been perceived as an educational support for mobilising and encouraging the acquisition of knowledge and skills in programmes. This failure shows that we must remain vigilant to avoid the same fate for EPI (Interdisciplinary Educational Practices, see 2.2.1.3).

2.2.1.3 New reform of Collèges (2016): towards more crosscutting teaching

Crosscutting teaching has always existed, but only marginally. This is the first time programmes include a mandatory share of crosscutting teaching through various systems instituted in the new reform of *Collège*s (2016).

The purpose of Interdisciplinary Educational Practices (EPI) is to bring together different kinds of knowledge and implement new skills through a project approach. Their content and goals make them close to the "themes of convergence" in the 2005 programmes (themes which were practically never implemented — *cf.* above). Now, the time dedicated to each discipline includes EPI: it is therefore essential for such crosscutting teaching to contribute to studying the disciplines concerned.

Moreover, in the framework of the new reform, evaluating students for the DNB (end of 3ème, age 14) will no longer be made on the basis of marks obtained in each of the subjects taught (including Chemistry and Physics), but in terms of the acquisition of the skills described in the five fields of Core Knowledge, Culture and Skills (see 2.1), which should result again in encouraging a crosscutting interpretation of such evaluations.

2.2.2 In *Lycées*

2.2.2.1 The reform of Lycées *(2010): towards better solving of "complex tasks"*

Following the reform of *Collèges* begun in 2005, the reform of *Lycées* of 2010 put even more emphasis on the notion the evaluation by skill, in keeping with the Core, and crosscutting teaching.

A scientific approach is now central to Chemistry and Physics programmes; it even serves as a common theme. The purpose of teaching is clearly expressed in terms of skills (see table below for a "problem-solving" activity), which must be clearly assessed.

Evaluating problem-solving skills
Taking on the problem
Analysing (establishing a problem-solving strategy)
Accomplishing (implementing the strategy)
Validating (view the results obtained critically)
Communicating the results

Figure 1: Problem-solving skills to be evaluated

Specific methodological tools were developed to enable teachers to help students perform what are called "complex tasks" in their learning activity:

documentary analysis and summary, problem solving, etc. New digital tools are actually very useful for such purposes (see 3.).

In scientific programmes in *Lycées* (S), some elements of the Baccalauréat were altered to ask students to solve scientific problems expressed simply, without providing any experimental protocol to solve it, but offering definitions, documentary texts and mathematical tools if needed. Students have to work on their own to find the different types of useful information and propose their own solutions.

It should be noted that this evaluation of skills emphasises the approach, and less the arithmetic calculation as the objective for evaluation itself.

Crosscutting teaching is also encouraged in this new reform of *Lycées*, in particular through "exploratory teaching" which leaves teachers free to engage their colleagues in interdisciplinary projects (2 hours weekly) and "customised support" which makes it possible to apply teaching, often with few teachers from all disciplines (including science), on subjects freely chosen, with no pre-established programme (2 hours weekly).

It should also be noted that, in 2nde, three initial themes structure the teaching of Chemistry and Physics — Sport, Health and the Universe — which can promote crosscutting interpretations of content with other disciplines like Life and Earth Sciences or Physical Education and Sport.

2.2.2.2 Feedback

Such scientific skills are still hardly present in the different activities proposed by teachers and, when they are, they concern mainly the experimental aspect or evaluation of specific activities like problem solving. Although some teachers admit they are more comfortable with standard transmission of knowledge, most assert that they have become aware of the importance of a structuring progression around the acquisition of skills. There is no consensus for evaluation, which in many cases remains standard.

Teachers more and more often implement active approaches, deemed more instructive and more conducive to explication of skills than more traditional approaches. In Vocational *Lycées*, the investigative approach is one of the approaches recommended by programmes, and activating strategies appear natural. On this theme, teachers in General and Technological *Lycées* clearly privilege experimental activities.

Certain obstacles have been observed in implementing investigative approaches:

- availability of the experimental material which actually conditions the approach;
- new rhythms imposed on students;
- lack of differentiation and an approach which leaves insufficient room for hesitation and backtracking inherent to the experimental approach (error management);

- overemphasis by some teachers on Mathematics at the expense of experimental practice, which must be highlighted;
- structuring knowledge**:** teachers must place students in open activity, while being careful later to identify what has been learned, progress and formalising knowledge.

Generally speaking, outside experimental activities, teachers find this active approach overly time-consuming, especially in 1ère S, where, in their view, the insufficient time allocated to teaching Chemistry and Physics makes it hard to implement this type of approach. It should be noted that, in both General and Technological *Lycées* and Vocational *Lycées*, teachers display remarkable mastery of “active learning”: genuine activating strategies for students, very effective, structuring work, discreet relevant regulation by teachers, implementing a monitoring grid for scientific approach skills. It should also be emphasised that some families find standard guided practices more reassuring in the context of more formal lecturing.

And it should be noted that teachers find it easier to change their teaching practices once the new activities requested have taken a more concrete form through examinations (Baccalauréat). Pressure by the establishment itself and by parents for students to succeed is determinant in this case.

The 2015 Baccalauréat S illustrated the difficulties induced by aligning Baccalauréat subjects with the goals expressed for these programmes, surely in part because of the very limited time for Chemistry and Physics in 1ère S.

Finally, we should note that teachers’ reticent attention to the “measurement and uncertainties” issue undeniably remains an improvement.

In all events, teachers must be concerned with giving meaning and consistency to all activities submitted to students, the necessary conditions for them to appreciate Chemistry and Physics and take full advantage of their training regardless of their own professional goals.
A skills-based approach also contributes to a more positive attitude for students through recognition of their right to structure their own training in a progressive personalised way.

Taken together, these observations attest to the difficulties confronting students in taking initiatives to implement complex tasks, whether quantitatively or qualitatively. The development of teaching practices, support of teams by inspection bodies and production of many resources since the new programmes were implemented lead us to believe that significant progress will be observed in coming years. In this respect, the retrospective effect of examinations on educational practices is becoming perceptible for problem solving. Students are increasingly being trained in this type of exercise, starting in 2nde.

3 Implementing new educational tools

3.1 Introduction

New digital tools can be used to help students in the learning activities imposed on them. They do not create new educational methods, but open the way for new forms of implementation.

Overall, using them makes students more active, because digital tools often facilitate students' self-evaluation, personalisation of their education, communication and assessment of their work, sharing and working in pairs, etc. Furthermore, they save time: their implementation can be short, efficient and targeted, as for short videos, for example.

The list of uses below describes possible uses as well as feedback noted locally.

3.2 Examples of uses

3.2.1 Interactive whiteboards

Interactive whiteboards (IWB) were introduced just after the year 2000 in French establishments; they require the use of video projectors. It is possible to act directly on an image on the screen using a stylus, with which you can write or click on the board, which acts as a screen. Publishing software is associated with the system, with its own file formats.

Today, the use of IWB is gradually being dropped in schools for the following reasons:

- Training and regular use are required for the software tools;
- Writing on the image with a stylus can be done more simply by projecting an image on a simple whiteboard and writing on it with felt-tip pens;
- The increasing availability of video projectors in classrooms makes it easier to screen images and videos without the need for an interactive board. A tablet connected to the video projector provides more relevant remote interactivity.

Basically, the IWB does not change the teacher's posture, standing near the board facing the students, without facilitating interactivity with them. Better alternatives are provided by less costly and more widespread tools like PCs, tablets, simple whiteboards, etc.

3.2.2 Video projector

Most classes in *Collège*s and *Lycée*s have video projectors. Their increasingly widespread use opens the way to changing practices. They help save time for teachers who can illustrate their teaching with appealing dynamic productions: animations, simulations or videos prepared in advance.

3.2.3 Voting devices

The educational system has shifted by making passive students become active. Another change is underway: the use of interactive tools. This educational practice is associated with specific equipment making it possible to have the students' answers instantly and orienting the discussion by taking into account the students' difficulties. To do so, teachers may use solutions ranging from the Internet to computer or smartphone applications, or separate voting devices vis-à-vis the Internet. This enables teachers to:

- identify students' representations of a concept or a notion;
- work on errors with collective remediation with the teacher or among peers;
- analyse the acquisition of teaching;
- adjust the presentation at the students' rhythm, thereby identifying problems.

For students, voting devices are tools for self-evaluation in relation to the group: they can also be reassuring in helping them realise they are not alone in having difficulties. It is also a tool for evaluating teachers in their practice (evolution at the end of the sequence). The atmosphere in the classroom is often more favourable to learning since it introduces "Learning to learn."

The advantage is that survey results appear instantly and remediation is immediate.

This technique is very effective in formative evaluation, which is often difficult or time-consuming otherwise.

Evaluation may be given marks, which provides for responsiveness in correcting errors. The results may remain confidential, with only overall percentages being posted. This type of equipment is very easy to set up. It is still quite costly (except for the use of interactivity by smartphone or computer). Few establishments are equipped at present, but more and more people are expressing their curiosity about this type of system and using it.

3.2.4 Production of videos

More and more educational videos made by teachers can be found on YouTube and other Internet sites. These short videos (2 to 10 minutes long on average), often called "capsules," enable students to re-examine a notion from another angle. Teachers can post links to videos on their establishments' websites and students can view them before or after class to complete their learning. This also helps shorten teaching time, which is more inclusive, making it possible to have more activities and exercises.

Some teachers may go so far as to practise flipped teaching, where the content of the course can be seen on a video before entering the classroom where only exercises are performed. This practice is hard to implement, however, since all students must have regular Internet access, which is not always possible, unfortunately.

Nonetheless, this is a growing trend. For the time being, the Ministry of National Education has not produced specific videos, and this must still rely on personal initiatives by teachers.

3.2.5 File-sharing software

In recent years, project approaches in all forms have taken up more and more room in secondary school teaching. During these projects, students undertake research, prepare and perform experiments in small groups (of 2 to 5 students) before an oral presentation. During such projects, teachers need to be able to monitor progress in the students' work and supply documents. It appears necessary to share resources: documents, photos, videos, etc. The establishments have internal networks that can do this, but students do not have access to them from their homes. Thus, more and more teachers use file-sharing software like Dropbox, Google Drive, etc. Some of this software can be used by several students simultaneously to alter files collectively.

3.2.6 Student help forum

On Internet, a student help forum was set up in particular for the sciences. Students in *Lycées* all over France thus have the possibility of asking questions 24h/7 on what they have not understood and teachers alternate to answer them. This system is funded and set up by the Ministry of National Education.

3.2.7 Online evaluation tools

The establishments' Internet sites enable teachers to post evaluations online and retrieve students' answers. It is even possible on the basis of multiple-choice questions, to associate a mark, which is added to the average automatically, which can be done using Google form-type Internet sites. Such practices still remain few, but they are growing. Some teachers, even if they are convinced of the added educational value, are reluctant for ethical reasons; they request the development of in-house tools from the Ministry of National Education.

3.2.8 Communication tools

Many establishments communicate through social networks like Facebook. The advantage of these sites is the possibility of providing information in real time, to get better acquainted and use the same tools the students use in private. Experimentation on Twitter is also underway, but some teachers have "ethical" reservations, because of these tools' "commercial" dimension.

3.2.9 Cognitive mapping

Cognitive mapping software is now integrated in the educational setting. Although still in limited use, it helps summarise an overall approach and analyse complex problems more clearly.

It is of great interest to students since it offers a simplified view of the knowledge to be acquired.

It is also possible for students to build their own cognitive maps simultaneously in collaboration. Unfortunately, the free software is not yet user-friendly, which can explain the reluctance to use this.

3.2.10 Digital tablets

The use of digital tablets for teaching has been experimented in different contexts by the Ministry of National Education.

For example, one of these experiments was conducted in a *Lycée* near Cité de l'Espace, in the town of Auch, about 100km from Toulouse. This *Lycée* equipped all educational players in 2nde (students age 15): 50 iPad2-type tablets were distributed: 35 for students + 13 for teachers + 1 at the documentation centre + 1 in reserve. All this equipment was acquired thanks to a Ministry of National Education subsidy.

Students could keep the tablets in their homes in order, on the one hand, to save on time and the cost of storing and charging them every night and, on the other, to enable students to acquired better mastery of the tool, while avoiding giving mandatory assignments to students not having an Internet connexion at home.

Tablets were used as the student' personal tools for school activities:

- **For the whole class**:
  - Research, notetaking in class;
  - Access to digital manuals available on the *Lycées'* network du (enhanced with videos, for example);
  - Digital notepads instead of paper notebooks;
  - Creation of a web-documentary or video;
  - Entry of information in the context of forms to facilitate surveys, information sharing, even tests;
  - Combined use of sound, video and text individually in language classes using a headset.
- **At home**: possible extension of classroom activities, students' personal work.

Generally speaking, the use of tablets was positive for the following points:

- Students' motivation, thanks to the use of a fulfilling learning tool which enables them to produce fine-quality results: digital books, web-documentaries, etc.);
- The educational efficacy of digital learning resources, like short videos, which are easier to use with individual tablets;
- Continuity between work in the classroom and at home;
- Development skills linked to project management: collective work encourages the development of project management skills, such as setting up a schedule, respecting deadlines, allocating roles in a team, validation steps, etc.

Certain drawbacks were also identified:

- Form may prevail over content: for example, students may spend a great deal of time fine-tuning a video to make it aesthetic rather than assimilating content;
- The development of collaborative work poses problems for individual assessment of students and determining each one's real investment.

Given this experimentation, the Ministry of National Education decided to provide all students in *Collège* (classes of 5ème, 4ème, 3ème) with digital tablets within the next three years. This ambitious project aims to facilitate the use of educational digital resources, whose production, validation and dissemination are a major educational issue in France in the coming years.

3.2.11 Classroom arrangement

Classroom arrangement is determinant for ensuring students' implication in this learning process.

It is best to have the students for small groups of 3 or 4 to promote discussion and remediation among students. The teacher should be able to move around easily in the classroom rather than maintaining a static frontal position, perceived as dominant. He/she becomes a facilitator for the students, who should be encouraged to remain active throughout the session.

Defining functional areas within the classroom itself can also contribute to easily identifying the different skills used during learning, such as documentary research, experimentation, and exchange and discussion.

Figure 2: Suggested arrangement of a dedicated educational facility at Cité de l'Espace

3.2.12 Free software

A great many types of educational software are available on the Internet. In particular, the American PhET site (https://phet.colorado.edu/en/simulation/acid-base-solutions) by the University of Colorado features many educational programmes Chemistry and Physics for all levels from Primary School to the University. They help develop very illustrative entertaining sequences of activities, although it may take some time for the students to learn to master the application itself. This means the students' "cognitive load" can focus more on using the tool itself than on the scientific notion it is intended to illustrate. Moreover, this kind of virtual illustration of a phenomenon should not replace the practical performance of an experiment to reach the same objective.

Figure 3: Using PhET educational software on wavelengths

For phenomena that are hard to reproduce or observe, the software tool is even more interesting. For example, Stellarium (http://www.stellarium.org/) software can simulate many astronomic phenomena in a very relevant, realistic way.

3.2.13 Using scientific instruments

French Physics teachers began learning to use IT between 1985 and 2000 thanks to EXAO (Computer-assisted experimentation) and ATIDEX (Computerised acquisition and processing of experimental data). Today, with the existence of many measuring instruments coupled with acquisition software, they are commonly used in schools. Some of these instruments are interesting for wireless measurement using digital tablets.

Figure 4: Globilab measurement acquisition device, coupled with a digital tablet

Using scientific instruments can now go all the way to remote control of a professional telescope, an activity proposed by the French IRIS project (http://iris.lam.fr/) set up and funded by several research laboratories.

Using a specifically developed software interface, the project enables students (from *Collège*s and *Lycée*s) to control directly a 500mm optical telescope located at the Haute-Provence Observatory (where the astronomer Michel Mayor discovered the first exoplanet in 1995). Since the telescope can be used for observation only at night, students can control it remotely only at night or in the early evening.

A call for projects is sent to *Collège*s and *Lycée*s at the end of the school year. Teachers who are interested send a project description (purpose of observations, outline of the project, type of students, dates they would like for using the telescope). Every year, a committee of experts selects over 40 projects all over France. They are organised in *Collège*s, *Lycée*s or Universities over a period of several months, often in "clubs," with a small number of students (approximately 15). The project is intended to develop students' knowledge on astronomy and using telescopes (small amateur telescopes are often used for direct observation along with remote control), project management, planning and respect for a schedule, decision making (what to do when there is a cloud cover and observation is impossible on the scheduled date?), responsibility (youngsters use a real instrument, protected nonetheless by safety rules).

The actual use of telescopes takes place in schools at night, until approximately midnight: students enjoy working at night, which makes their activity truly exceptional. It should be noted that students (and teachers) can practise using a telescope thanks to a special simulation tool.

Other programmes for controlling telescopes are available elsewhere in the world, but this project is easy to use since the telescope is dedicated exclusively for school use, which makes it available year round, and the software and documentary tools are all in French, which makes it simpler to use.

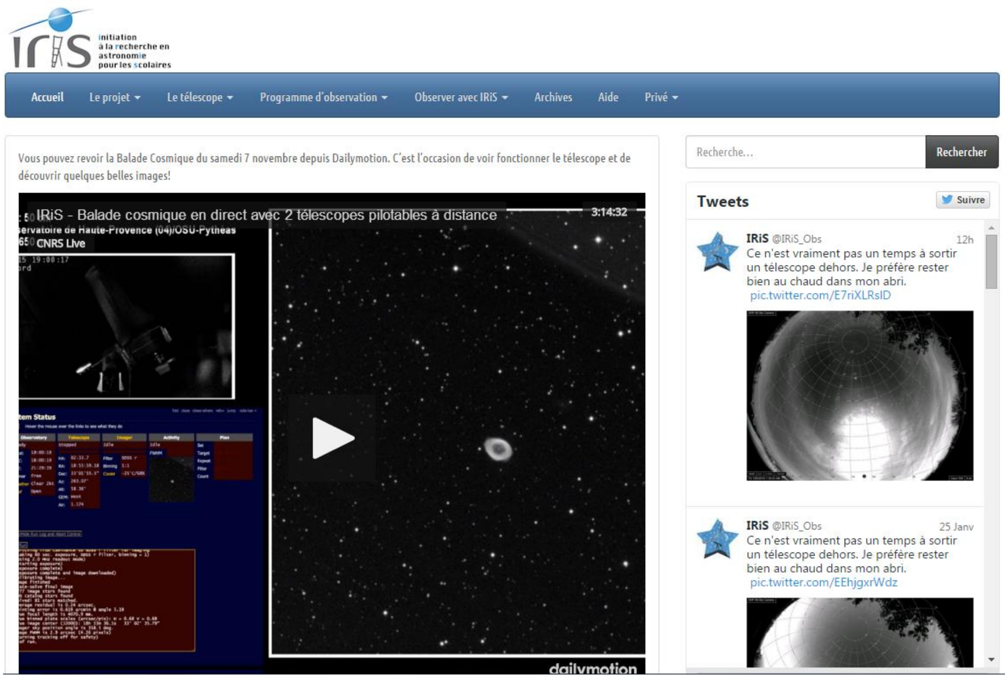


Figure 5: Homepage of the IRIS website, presenting the interface for controlling the telescope

3.2.14 Participative science

New participative science projects enable students to participate actively in a genuine research project, in Astrophysics for example, collecting data or helping in their analysis. A guide in French helps teachers choose which activity: tracking meteorites, detecting dangerous asteroids, monitoring lighting pollution, etc. https://www.afastronomie.fr/astronomie-participative.

4 ANNEX

4.1 Schedules (6, 2016) (7, 2016)

COLLÈGE

Levels	Physics-chemistry (hours / year)
5$^{\text{ème}}$	**48 h**
4$^{\text{ème}}$	**48 h**
3$^{\text{ème}}$	**64 h**
Total collège	**160 h**

LYCÉE (scientific options)

General Education		Industrial technological Education		Laboratory technological Education Laboratory physics and chemistry	
2nde	**96 h**				
1ère S	**96 h**	1ère STI2D	**96 h**	Première STL-PCL - Physics-chemistry - Chemistry-biology-living - Mes. and instruments - PCL speciality - ETLV[5]	Total 512 h - 96h including 1/3 chemistry - 128h including ½ chemistry - 64h including ½ chemistry - 192h including ½ chemistry - 32h including ½ chemistry
Specific Terminale S	**160 h**	Terminale STI2D	**128h**	Terminale STL-PCL - Physics-chemistry - Chemistry-biology-living - PCL speciality - ETLV	Total 608 h - 128h 96h including 1/3 chemistry - 128h 96h including 1/4 chemistry - 320h including ½ chemistry - 32h including ½ chemistry
Terminale S speciality	**64 h**				
Total S program including speciality	**416 h**	Total STI2D program	**320 h**	Total STL-PCL program	**1216 h**

4.2 Curriculum (8, 2016) (9, 2016)

General themes in physics in Lycée

Levels	Teaching	Themes
2nde	Core curriculum	Health Sport Universe
	Exploratory teaching « Scientific methods and practices »	Sciences and food, Sciences and cosmetology,

		Sciences and police investigation, Science and risk prevention
	Exploratory teaching « Sciences and laboratory »	Geosphere, Earth atmosphere, physics-chemistry of living materials, ways of life, pollution and risk prevention, contemporary energy concerns, information and transmission

1ère L et ES	Scientific teaching	Feeding humankind Worl visual representation Energy challenge

1ère STI2D-STL, Terminale STI2D-STL	Physics-chemistry	Clothes-coating, habitat, transport, health
1ère STL Terminale STL	Chemistry-biochemistry-Living sciences	The living : composition, fonctioning, matter, energy and information exchanges
	Speciality teaching Laboratory physics and chemistry	Images, Waves Chemistry and sustainable development : chemistry synthesis and analysis Systems and process

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4.4 Citations

1. (2015). Consulté le 2016, sur Ministère de l'Education Nationale: http://www.education.gouv.fr/cid162/les-grands-principes.html

2. (2016). Ministère de l'Education Nationale. Consulté le 2016, sur http://www.education.gouv.fr/cid214/le-college-enseignements-organisation-et-fonctionnement.html

3. (2015). Ministère de l'Education Nationale. Consulté le 2016, sur http://www.education.gouv.fr/cid215/le-lycee-enseignements-organisation-et-fonctionnement.html

4. (2014). Ministère de l'Education Nationale. Consulté le 2016, sur http://www.education.gouv.fr/cid195/les-chiffres-cles.html

5. (2016). Ministère de l'Education Nationale. Consulté le 2016, sur http://www.education.gouv.fr/cid2770/le-socle-commun-de-connaissances-et-de-competences.html

6. (2016). Ministère de l'Education Nationale. Consulté le 2016, sur http://eduscol.education.fr/cid46763/les-cycles-college.html

7. (2016). Ministère de l'Education Nationale. Consulté le 2016, sur http://eduscol.education.fr/pid23167/lycee-d-enseignement-general-et-technologique.html

8. (2016). Ministère de l'Education Nationale. Consulté le 2016, sur