Consultant Report
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STEM: Country Comparisons

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Literature Review
STEM Education in France

Elodie de Oliveira
Organisation for Economic Cooperation and Development

Kelly Roberts
University of Melbourne

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Executive summary

The following review of STEM education in France was conducted by Elodie de Oliveira from the Organisation for Economic Cooperation and Development (OECD) and Kelly Roberts from the University of Melbourne. The review covers the areas stipulated by the project brief, including stakeholder attitudes to STEM education and careers, patterns of STEM provision in school and tertiary education, student engagement in these programmes, labour market outcomes for graduates, and strategies or organizations with a role in enhancing STEM participation. The focus has been on the period since 2005.

This review first provides an overview of the French school and tertiary systems, including a description of the curricular coverage of STEM fields at each level and along each academic, professional or vocational pathway.

Early childhood and primary education levels are much the same in France as Australia. Students move from primary to lower secondary, or *Collège*, and then upper secondary school. It is at this point that the pathways split most significantly, with a variety of choices available to students. Upper secondary school includes three main programmes: the academically-oriented *Baccalauréat Général* (final three years of high school), the professionally-oriented *Baccalauréat Professionnel* (similarly three years), and the vocationally-oriented trade diplomas known as the *Certificat d'Aptitude Professionnelle* and the *Brevet d'Études Professionnelles* (both two year programmes), chosen according to the preferred trade specialization. The *Baccalauréat Général* is the most common pathway at upper secondary level. Careers in STEM fields can lead from each of the three programme pathways. However, it is primarily graduates of the *Baccalauréat Général* who proceed to high level research positions in STEM fields, as these areas of study are covered most thoroughly in this programme. More specifically, it is the graduates of the sciences major strand (rather than the economics and social sciences, or literature major strands) within this programme who follow such career pathways.

The alternative pathways available at tertiary level are, of course, far more varied and complex. Like Australia, France has vocationally, professionally and academically-oriented study pathways ranging from two year technical diplomas at trade schools and institutes of technology, to three year Bachelor programmes at university, to post graduate study trajectories that continue up to eight years or more after high school through Masters and PhD level programmes. The majority of students who engage in tertiary level studies in France attend universities, and their programmes of study align with the consistent European structure outlined by the Bologna Process. A large variety of STEM-related courses and programmes are available at each level. Enrolments in, and graduations from, STEM-related courses of study at tertiary ISCED levels 5 and 6 in France exceeds both the OECD and European Union (EU) averages, and is also higher than in Australia. However, the country remains concerned both that the proportion is not high enough to satisfy ongoing economic needs, and that the percentage of tertiary students following these directions declined throughout the 1990s and 2000s.

While France performs comparatively well internationally, the problem of low and declining participation in STEM education persists there too. The review provides information about French attitudes to STEM education, factors that influence student motivations and an analysis of gender balance in STEM fields in France.

An increase in the number of researchers, particularly in STEM-related fields, is an economic priority for recovery, stability and growth in the coming years. However, in the past couple of decades, developed countries around the world, including France, have experienced a significant decline in the proportion of students choosing these fields of study and pursuing research pathways. The most dramatic changes in France occurred during the late 1990s, and while it must be acknowledged that France has made some progress to stabilize these figures in recent years, the problem does persist.

At the upper secondary level, the sciences major strand of study is by far perceived to be the most prestigious, leading to any further studies the graduate may wish to choose. However, not all graduates in this strand are motivated by a passion for the sciences. In a bid to improve this situation through the development of students' understanding of science careers, further links with the scientific community are being established. Although science and engineering careers are generally desirable and prestigious occupations, the length of tertiary studies required tends to deter students. This is, therefore, a potential avenue for future action.

Research reveals a combination of influences and determining factors of student motivation to select STEM fields of study, and then their consequent performance in these courses. These influences include student factors – home background, attitudes and self-efficacy – and external factors – the nature of the learning environment and teaching styles experienced during early studies within these fields. The international evidence reveals that a students' home background, their attitudes and their self-confidence in learning have a significant impact on student curricular choices and performance levels exhibited at school. Further, teacher specific factors are also significantly influential. Importantly, all these elements have the potential to shape students' post-secondary education and career choices, and so are key areas to influence ongoing participation in STEM fields.

The under representation of women in scientific and other STEM-related professions is a significant and ongoing issue. In the mid-2000s, 30% of those researchers employed across EU-15 countries were women, in contrast with the overall 44% of employed persons and 46% of all professionals who were female. Specifically in France, only 32% of scientific researchers in the public system (universities and research institutes/centres) are women. Their promotion to senior positions and inclusion in selection and decision-making bodies are also less than equitable, with women accounting for only 24% of such appointed committee members in this country.

Gender imbalance within the STEM professions can be traced back to career ambitions, course selection and attitudes of young women in initial education. Much effort has been put into improving the participation of women in science and other STEM fields. Over some twenty years, slow progress has been made, with the number of girls choosing the science major track in the *Baccalauréat Général* programme having tripled over this time to reach 46% in 2011, and achievement levels following suit. Despite such gains, gender patterns in terms of professional direction, subject choices, and achievement levels persist, with the worst situation remaining in pathways dominated by the sub-disciplines of engineering, physics and mathematics. It is important to note that comparatively speaking, both Australia and France perform above the OECD average, with France also outperforming Australia on almost all of the presented gendered measures.

> *Having recognized the problems, the review turns to strategies used in France to enhance STEM education in the classroom, through local or national initiatives and via the work of research associations, institutes or centres.*

Classroom strategies have been adopted in France to boost interest in studying STEM fields. Recent reforms to mathematics education added content to the upper secondary curriculum, brought more focus to procedural skills and problem solving, and promoted cross-curricular links, particularly with technology and science. Very recently, an initiative was devised to promote science education through building curriculum synergies during earlier school levels, connecting science studies with everyday life experiences and real world problems, and promoting careers in STEM fields. Furthermore, national tests of skills and literacy in mathematics and sciences have been introduced for the purposes of monitoring educational performance and can be additionally used to observe achievement of students in these discipline areas.

Various national and local municipal initiatives have been used in recent years to promote STEM studies. For example, Sciences at School works to encourage extra-curricular science activities for secondary school students, including clubs and various projects. A major strength of this programme is the national network created. The EU has done much work on boosting education in STEM fields, coordinating several projects within France itself, such as the *J'aime les Sciences* programme which targets individual participation and performance in science within primary and lower secondary schools through personalized approaches that focus on student self-confidence and motivation to study STEM subjects. National bodies are responsible for the administration of contests and technical workshops/programmes for young people around the country. These have become quite popular, thought to improve students' cognitive skills, as well as non-cognitive abilities that enhance their ability to participate successfully in STEM study. Other programmes and awards are targeted at the promotion of STEM fields for women and girls to improve their experiences in these fields of education and, hopefully, encourage their pursuit of STEM-related careers.

Several research bodies in STEM domains conduct research in relation to the enhancement of STEM education. The review describes a selection of these.

Bumping into hurdles and limitations while conducting this review

The research leading up to this review was conducted thoroughly and systematically. However, some hurdles were encountered by the authors. One of these was a lack of use of the collection of curricular fields in the term *STEM*. While obviously linguistically specific to Anglophone contexts, the collection of science, technology, engineering and mathematics was not often used to structure the research or policy literature identified. Consequently, resources for this review were instead found through a more rigorous search process for each component of STEM individually. That is, separate searches were conducted for research and other programmes that had concentrated on science, technology, engineering or mathematics education. Another hurdle encountered in the research and review process was the lack of data collected by French educators and policy makers. Several international reports identified a lack of data specifically from France as a result of cultural and political factors in the country (e.g., European Communities, 2004, 2008; European Roundtable of Industrialists, 2009; OECD, 2008).

The study of STEM fields within French schools

Understanding French education: An overview of schooling

The French education system has a deserved reputation for being highly centralized and complex. The foundations of the current system were laid between 1871 and 1946, when the Third Republic and its Minister for Public Instruction, Jules Ferry, instated a system of secular, free and compulsory schooling. Since 1959, school attendance has been compulsory for children up to the age of sixteen. Educational policy-making and its implementation are the responsibility of the government, except for “the fundamental principles of education” which are dictated by laws voted on by Parliament (Ministère de l’Éducation Nationale, 2012d). These principles are set out in the 1989 Framework, in which education is clearly considered to be a national priority. Furthermore, responsibility falls to the State to promote equality of opportunity for all and to provide an education system that prepares young French citizens to become the nation’s human capital.

The majority of French schools are administered by either the State or a local authority. Many private schools even have some sort of contract with the State and possess a similar organizational structure. Students are allocated to schools according to their district of residence, creating an incentive for parents to choose private over public schooling. Decisions about curriculum content, teaching objectives and activities are made centrally in France in an attempt to implement egalitarian ideals. While it may seem that this homogeneity could achieve equity across the system, supporting diversity and ensuring all students are provided with the same opportunities, the district-based allocation of students substantiates the converse argument. As in Australia where students are also required to attend local schools, children in France usually attend school with peers from their own or similar socio-economic background, creating a disadvantaged educational environment for those from such communities.

Every child is entitled to attend a state operated school from 3-16 years of age, however schooling is only deemed compulsory from the age of 6 years. Many children attend nursery school, known as *École Maternelle* from the age of 2, most commonly for up to 4 years before they begin elementary school, which is known as *École Élémentaire*. Elementary school lasts for 5 years, from age 5-11, and is composed of five levels: CP (Preparatory Course), CE1, CE2 (Elementary Courses), CM1 and CM2 (Middle Courses). The CP and CE1 constitute students’ basic learning, while the CE2, CM1 and CM2 is directed more toward knowledge consolidation. Nursery and elementary school form what is commonly known as primary school, in French *École Primaire*.

Students attend secondary school for 7 years, from 6^{th} grade until their final year of schooling. Secondary school is divided into a lower school, known as *Collège*, 4 years duration, and an upper school, known as *Lycée*, for the final 3 years. In the last two years of the *Lycée*, students sit national examinations in order to prove their learning through secondary school and gain entry to university. This programme, known as the *Baccalauréat*, allows students some choice. In the general branch, they may choose between three tracks of studies: (1) Literature (L), a stream mainly based on French, philosophy and modern languages; (2) Economics and Social Sciences (ES), an alternative stream based on these two disciplines; and, (3) Sciences (S), a stream focused on the study of mathematics, physics and the natural sciences. The *Lycée Général* underwent some rather substantial structural changes in 2010. Through these reforms, France joined the international shift toward personalized and student-directed learning, in order to enhance individual liberty and allow students to orient their studies to accord more closely with their professional ambitions. Indeed, courses have been added to the curriculum in the class of *Seconde*, allowing students from this track to choose from 10 to 13 different courses. Some of these are in STEM fields. For instance, subjects such as Engineering have been introduced to stimulate student interest in such fields and facilitate entry into higher education. More details of the subject offerings available within the *Lycée Baccalauréat Général* programme are provided in a later section.

The *Lycée Général* programme is only part of the senior secondary educational offering in France. Students have several alterative tracks from the age of 14 years. Those who are not able to gain entry to the *Lycée Général* can choose to undertake one of two more vocationally oriented educational programmes. These were revised in 1985 with the aim to create stronger linkages between vocational training and industry. Specifically, the 1993 legislation states that all students should be offered at least vocational training before leaving the educational system, regardless of their previous educational achievements (Dorier et al., no date). This revision has resulted in the creation of a professional baccalaureate, known as the *Baccalauréat Professionnel*, and two trade diplomas, known as the *Certificat d'Aptitude Professionnelle* (CAP) and the *Brevet d'Études Professionnelles* (BEP). Within the professional baccalaureate, there are four tracks: (1) Industrial Sciences and Technology (STI); (2) Laboratory Sciences and Technology (STL); (3) Management Science and Technology (STG); and, (4) Social Sciences and Health Technologies (ST2S). Within each, students are offered the opportunity to choose their specialization, similar to the process of selecting majors in most Australian tertiary degrees but on a slightly smaller scale. The vocational upper secondary programme is provided to French students who perform poorest during lower secondary school. This programme consists of the two national vocational and trade diplomas, the CAP and BEP, each two years duration. The proportion of students enroling in these professional and vocational programmes at senior secondary level, rather than the more academic *Baccalauréat Lycée Général* programme has risen by more than 40% since 2005, to reach 40.3% of all upper secondary students by 2011 (see Figure 1). In 2011, over 150 000 students were enroled in their final year of the *Baccalauréat Professionnel* programme in public schools, and more than 33 000 were enroled in private institutions, with almost another 150 000 enroled in the vocationally oriented CAP and BEP programmes in the same year (see Figure 2). Despite this substantial increase, the *Baccalauréat Lycée Général* remains the largest programme, with the majority of students opting for this, more traditional, academic education experience (Ministère de l'Éducation Nationale, 2012b).

Figure 1: The increase in the proportion of upper secondary students enroled in the professional and vocational programmes. The remaining students not represented in this figure are enroled in the Baccalauréat Lycée Général. This graph is sourced directly from Ministère de l'Éducation Nationale (2012b).

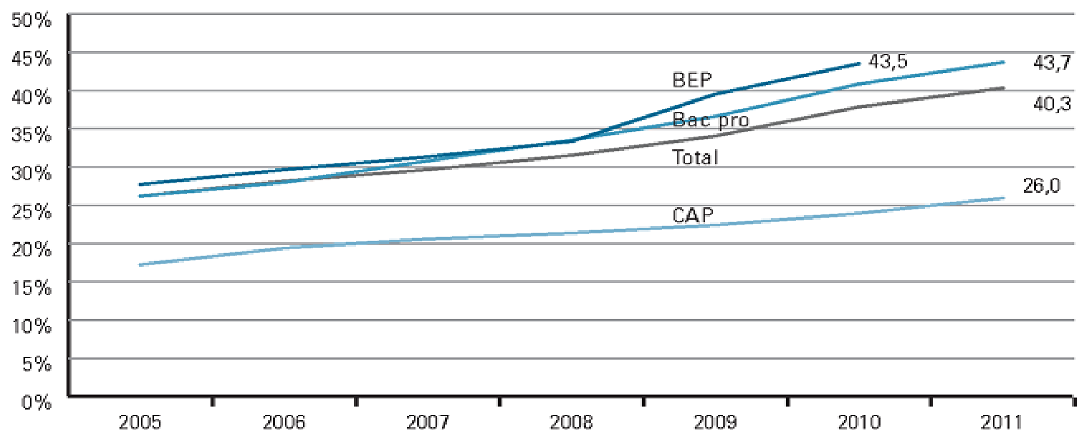
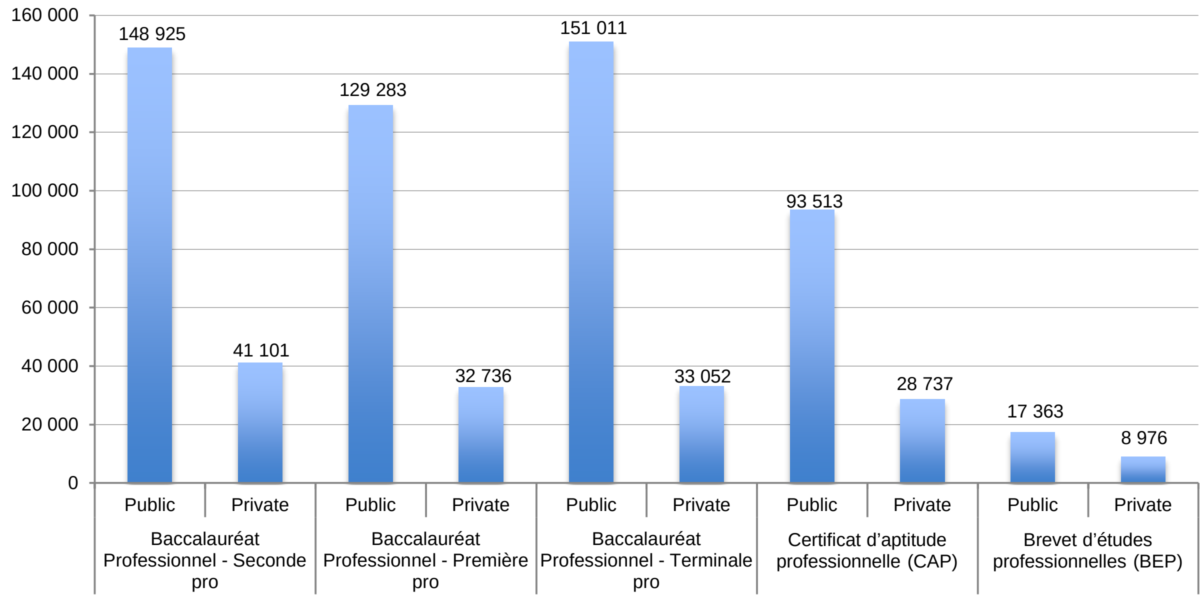


Figure 2: The number of students choosing professional or vocational branches of secondary education in France in 2011. Data sourced from Ministère de l'Éducation Nationale (2012b).



The coverage of STEM throughout French schooling

Primary school: Elementary levels

Within the main stage of primary schooling, *École Élémentaire* or Elementary School, students study mathematics, as well as experimental and technological sciences from the STEM group of disciplines.

- *Mathematics*

Students acquire early mathematical knowledge about geometric shapes, numbers and become acquainted mathematical aspects of the concepts of space and time. This knowledge is normally developed through a variety of exercises and games, which assist the formation of logical thinking, particularly through the organization, comparison and classification of objects. During elementary schooling, students study mathematics for 5 hours each week, a total of 180 hours each year. At this level of French education, there are two priorities for the study of mathematics: the development of problem solving, the primary basis of all mathematical learning, and mental arithmetic, the goals for which are the memorization of basic results and the capacity to elaborate computational processes.

The elementary syllabus is organized around five domains:

1. **Exploiting numerical data:** Students should be able to solve most problems involving the four operations, including the addition and subtraction of decimals, and multiplication of decimal numbers by an integer.
2. **Integers:** Students develop their capacity to order, compare and classify numbers.
3. **Arithmetic:** Students engage in mental computations in order to learn multiplication tables and engage with simple subtractions and multiplications. Pupils are encouraged to learn to use a calculator.
4. **Space and geometry:** Students should develop their understanding of ordinary space through the study of its representation through maps and plans. Geometrical properties are also studied, including perpendicular and parallel lines, equality of length, angles and axes of symmetry. Further, students learn to use tools, such as a ruler, set square and compass. They also develop their ability to characterize basic three dimensional shapes, including a cube and other right-angled

parallelepipeds, as well as plane figures, including a square, triangle, rectangle and circle.

5. **Magnitudes and measurement:** Students learn about the notions of length, mass and capacity throughout their first two years of elementary level education. This knowledge is later put into context through the comparison and measurement of objects using standard units. Students develop their ability to estimate, apply standard measures and understand their relationships, making calculations about notions like perimeter with this information.
6. **Fractions and decimal numbers:** The sixth learning domain is added in order to consolidate student learning in the final three years of elementary schooling. Fractions are studied to the extent required to understand decimal numbers, with the ability to use operations not required at this level. The main goal of learning decimals is to master the principles of the representing numbers with a comma (like the decimal point used in mathematics in Australia) so that students can understand the magnitude of each digit in a number according to its position (Ministère de l'Éducation Nationale, 2012c).

- *Experimental and technological sciences*

At Elementary School in France, students are initiated into the techniques of investigation, intended to spark their curiosity in science and technology, and develop their critical thinking skills. The objective is to improve students' understanding of the world, both natural and man-made elements. From the elementary level of CE2 to the middle school level of CM2, students participate in 78 hours of experimental sciences each year.

Lower secondary school: Collège levels

Collège students engage primarily in both problem solving and investigation intended to encourage students to thinking critically about their world, understand mathematical principles and solve mathematical problems.

- *Mathematics*

The objective of *Collège* level mathematics is to develop both reasoning and analytical skills, while providing students with a basic acculturation into the basics of mathematics. In their first year, students participate in 4 hours of mathematics study each week. This reduces to 3.5 hours in each of the following three years of *Collège*.

The curriculum is organized around three domains:

1. **Geometry:** The study of "simple" figures begun in elementary school is deepened at this middle level, and the study of magnitude is now included in geometry. Students develop their ability to reason and 'prove' mathematical principles through experimental activities vis-à-vis the properties of parallelograms, rectangles, and so on. An emphasis is put on the triangle as a new area of learning, triggering its own challenges, such as the sum of its angles, construction problems, the Thales and Pythagorean theorems. Finally, the study of vectors is introduced, yet limited to notions of sums.
2. **Numbers:** Problem solving is the main goal of this part of the syllabus. Through problem solving, students learn how to: identify and formulate questions, develop hypotheses and experiment on examples, construct an argument, control the results obtained by assessing their relevance, communicate research and develop solutions.
3. **Data organization and management – Functions:** Students study here proportionality and statistics. In other words, they explore percentages, calculate magnitude and unit conversion (length or area), and study the statistical representation of data through the use of graphs and tables. In the last year of

Collège, students study proportionality, as well as the geographical representation of functions (Ministère de l'Éducation Nationale, 2012c).

- *Science: Physics and chemistry*

The teaching of physics and chemistry starts in the fifth year of *Collège*. Students acquire a basic understanding of scientific principles and method through the study of a selection of domains within the disciplines of physics and chemistry. These domains include substances, light, electricity and gravity. The aim is to spark students' curiosity, develop their observation skills, and begin to interest them in the process of scientific discovery (Ministère de l'Éducation Nationale, 2012c).

- *Science: Life and earth sciences*

The main objective of teaching these discipline areas is to enable *Collège* students to acquire an understanding of the workings of the human body, the living world, the Earth and the environment. Students observe phenomena and living organisms, undertake experiments and develop hypotheses. Through a variety of exercises, the intention is to give students an opportunity to become aware of the importance of, and responsibility each has towards, the environment and health of ourselves and others (Ministère de l'Éducation Nationale, 2012c).

- *Technology*

Students study a variety of technologies to acquire the methods and knowledge needed to understand the function of technical, man-made objects and machines.

- *Integrating learning in science and technology*

A pilot programme is currently in progress in a few volunteer lower secondary schools to integrate the teaching of science and technology in 5th and 6th grade. This curricular offering covers the content of physics and chemistry, life and Earth sciences, and technology. However, the material is presented in an integrated, rather than discipline specific, manner (Ministère de l'Éducation Nationale, 2012c).

Upper secondary school: Baccalauréat Lycée Général

Curriculum differentiated according to study orientation chosen

Upper secondary students in the *Baccalauréat Lycée Général* programme share the same curriculum in the first year of this programme, known as *Seconde*. In the *Première* and *Terminale*, or final two years of this programme, the teaching of science then depends on the major strand chosen by each student, whether it be *Littéraire* (L), *Sciences Économiques et Sociales* (ES), or *Sciences* (S). An examination of the teaching time devoted to each STEM-related subject reveals that mathematics is valued less than the combination of sciences in each strand (see Table 1). Mathematics is compulsory, but for science majors, it seems to be afforded less importance than science fields, such as engineering (see also Table 1). Moreover, a study of this feature of upper secondary education shows that within examinations of *Baccalauréat Général* studies, questions regarding Mathematics are weighted at only less than 20% for S strand students, and significantly less in the ES and L strands (Dorier et al., no date). Indeed, the weighting of such disciplines in the S strand is what justifies the label of this track 'scientific'. However it remains a generalist education, with significant weight dedicated to other disciplines outside science and mathematics, as reflected in the summed coefficient of scientific and non-scientific subjects of the of *Baccalauréat Général* programme (see Table 2).

Table 1: Teaching time devoted to each STEM-related subject within all tracks of the Première and Terminale levels of the General Baccalaureate programme. Data sourced from Ministère de l'Éducation Nationale (2012a).

Curricular Track	Mathematics	General Sciences (specific to L and ES students)	Physics and Chemistry	Life and Earth Sciences	Engineering	Computer and mathematical sciences
Premières						
S	4hrs	X	3hrs	3hrs*	7hrs*	X
L	3hrs*	1.30hrs	X	X	X	X
ES	3hrs	1.30hrs	X	X	X	X
Terminales						
S	6hrs**	X	5hrs	3.30hrs**	8hrs**	2hrs*
L	4hrs*	X	X	X	X	X
ES	4hrs**	X	X	X	X	X

*Note: ** refers to optional advanced courses; * refers to optional courses; and X refers to unavailable courses.*

Table 2: Weighting of scientific and non-scientific subject examinations within the three tracks of the Baccalauréat Général. Data sourced from Inspection Générale de l'Éducation Nationale (2007).

Curricular Track	Science (S)	Economic and Social Science (ES)	Literature (L)
Weighting in scientific subjects	21	7-9	4-7
Weighting in non-scientific subjects	17	28-30	30-46
Total	38	37	37-40

Note: Indications, such as 7-9, correspond to the optional courses and courses of specialization.

Prior to reforms of the *Lycée* programme in 2010, the most significant innovation to mathematical education was the introduction of investigations during the *Première* year of study known as the *Travail Personnel Encadré* (TPE). The TPE involved students undertaking supervised individual work and small group work towards the production of a collective project on their own chosen topic relevant to the national interest. These projects are required to integrate at least two disciplines essential to a student's programme of study and are undertaken in dedicated extended weekly sessions. The TPE work produced is eventually assessed through both oral and written presentations by teachers from each of the disciplines drawn from in the project (Dorier et al., no date). The overall programme reforms also brought changes to mathematical instruction. For example, computers and other technologies have been included in instruction and even baccalaureate examinations, and a greater emphasis is now placed on the links between mathematics and other disciplines, such as the sciences.

STEM in the Baccalauréat Général upper secondary programme

Significant teaching time is devoted to STEM studies within the *Baccalauréat Général* programme. Students in the first, or *Seconde* year of their baccalaureate study mathematics for 4 hours per week, covering a range of topics, including functions, geometry, statistics and probabilities. These students also undertake study in physics and chemistry, exploring health, the practice of sport and the Universe for 3 hours each week. However, only 1½ hours each week are devoted to the study of life and Earth sciences. This discipline is covered by three topics: the human body and health, the planets, the Earth in the Universe, as well as the evolution of life. During this first year, students also engage in two exploratory topics for another 1½ hours each per week. One of these must be a STEM-related subject, such as biotechnology, science and the laboratory, health and society, invention and technological innovation, engineering, or scientific research methods (Ministère de l'Éducation Nationale, 2012a; Ministère de l'Éducation Nationale, 2012c). Interestingly, while language, literature and society courses are also offered, the majority of modules on offer are scientifically oriented.

In the following two years *Première* and *Terminale*, L and ES (humanities and social science strands) students study some physics, chemistry, life and Earth sciences. These subjects provide students with an understanding of the questions and issues in relation to scientific phenomena they will find directly relevant to everyday life. In both of these study tracks, these subject domains are encompassed in one compulsory general science course. The study of mathematics here is similarly directed towards the use of mathematics in everyday life and work. The course syllabus covers tables of numbers, percentages, statistical parameters and graphical representations. The study of mathematics is no longer compulsory for students majoring in Literature (L). They have merely the option to engage in mathematics in their final two years: 3 hours per week in their *Première* year and 4 hours in their *Terminale* or final year of secondary study. In this optional course, students also cover geometry, while all other topics from their compulsory mathematics course in their *Seconde* year is deepened. Students majoring in Economic and Social Sciences (ES), must undertake up to 3 hours per week in their *Première* year and 4 hours in their *Terminale* or final year of secondary study. These students have an additional option to undertake an advanced course in mathematics, raising their weekly contact time in this area by a ½ hour each week (Ministère de l'Éducation Nationale, 2012a).

Students of the sciences (S) track in the *Baccalauréat Général* programme of French upper secondary schooling study the most mathematics and sciences. This study is focused on research activities with students learning scientific methods, notions and concepts, especially through experimental activities. Engineering can also be undertaken in preference to life and earth sciences from *Première,* the second year of upper secondary. This subject develops student understanding of complex technological systems, encouraging reflection on relevant environmental and societal issues. Finally, students of the Sciences major track undertake computer sciences. This is an optional subject only recently introduced with the intention of preparing students to pursue further studies and careers in the field.

Upper secondary school: Baccalauréat Lycée Professionnel

The professional branch of upper secondary primarily aims to prepare students with minimum qualifications for the workforce. It is essentially a vocationally oriented training programme based on a general education (French, mathematics, a foreign language), technological education and some periods of industry internship or apprenticeship. Mathematics is taught at every stage of the *Baccalauréat Lycée Professionnel* for 2 hours per week, although the curriculum varies according to specialization. Students build mathematical understanding that is intended to enable them to resolve issues they encounter in life and work. All courses here teach derivation and integration, logarithms and exponential functions, statistical series built on two variables, differential equations, probability and normal distribution (industry sector only), and mathematics for management (tertiary sector only). The professional baccalaureate also includes a sciences component covering several disciplines, including physics, chemistry and technology.

Students enroled in the Industrial Sciences and Technology (STI) track, engage in technology studies for industry through the exploration of materials, energy and information. Societal issues, such as sustainable development, are examined here. In contrast, the Laboratory Sciences and Technology (STL) track centres primarily upon laboratory activities related to the study of life and the environment. Their study of physics and chemistry explores similar themes through these dimensions. Students in both STI and STL tracks engage in mathematics, physics and chemistry, concentrating on methods for problem solving and links to industrial and laboratory technology. Fundamental concepts in these disciplines are also covered. A similar programme of science, mathematics and technology is provided to students in the Management Science and Technology (STG), Social Sciences and Health Technologies (ST2S) and other professional tracks and so are not discussed further here (Dorier et al., no date; Ministère de l'Éducation Nationale, 2012a).

Upper secondary school: Vocational branches

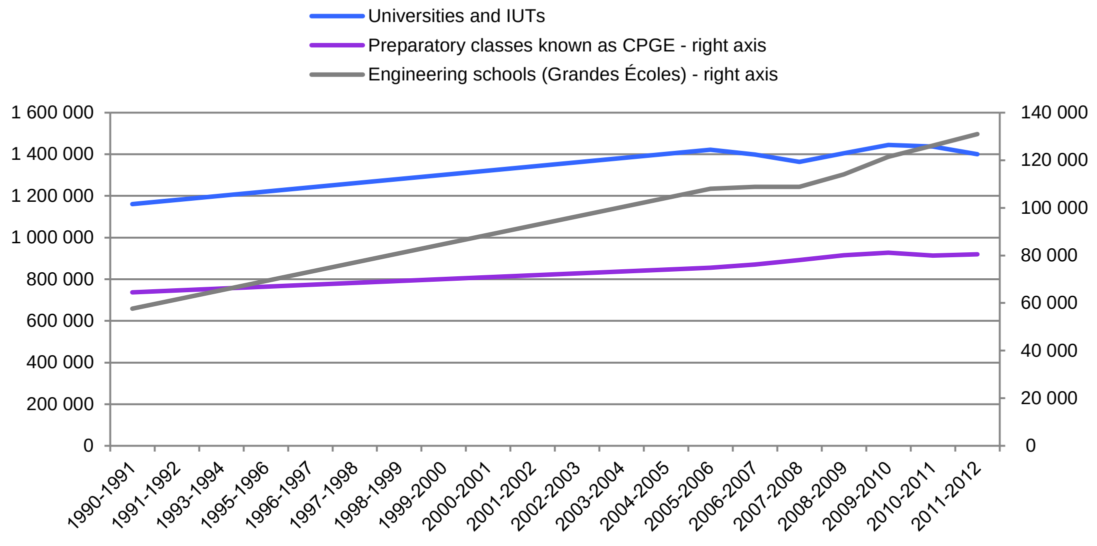
The students of the *Certificat d'Aptitude Professionnelle* (CAP) and the *Brevet d'Études Professionnelles* (BEP) vocational programmes of upper secondary French education are also working towards a minimum qualification but with different content and purpose. The BEP teaches skills in the more demanding technological areas, for which professional integration requires higher qualifications. Many BEP students will continue further studies to complete the technological and vocational baccalaureate, allowing them to pursue higher qualifications at tertiary level later. The CAP, on the other hand, provides practical skills in particular areas, allowing for immediate vocational application. The teaching focus in mathematics for BEP and CAP students is to ensure that they acquire the skills that will allow them to solve real-world workplace problems. In BEP, 2-3 hours per week are dedicated to this discipline, while CAP students receive only 1½-2 hours each week over their two-year course. A similar industry focus to the professional baccalaureate programme exists here, although there is a lower level of academic complexity demanded (Dorier et al., no date).

The study of STEM fields within French tertiary level education

Understanding French education: An overview of tertiary education

The basic principles for tertiary education in France were established in 1984. The Ministry of Higher Education holds responsibility for the conduct of public establishments, although institutions retain management autonomy with regards to teaching, academic content, administration and finance. Entry into tertiary education is open to all students with a baccalaureate and there are no geographical constraints on admissions. There are several forms of post-secondary education in France: (1) *Classes Préparatoires aux Grandes Écoles* or Preparatory Schools, known as CPGE; (2) the *Brevet de Technicien Supérieur* or Advanced Technician Training, known as BTS; (3) the *Institut Universitaire de Technologie* or Institutes of Technology, known as IUT; and, (4) the Universities. By far, the majority of tertiary students attend universities, although the recent increase in students enroling in programmes at *Grandes Écoles*, particularly in engineering, is worth noting (see Figure 3). Each type of institution is organized differently and faces distinct policy issues (Ministère de l'Enseignement Supérieur et de la Recherche, 2012). Furthermore, and importantly here, education within STEM fields is delivered quite differently within each.

Figure 3: Number of enroled tertiary students by type of programme. Data sourced from Ministère de l'Éducation Nationale (2012b).



The *Classes Préparatoires* or CPGE are preparatory classes for entry to top universities. Students attend these two-year, fast paced courses that are conducted within high schools in major cities across France. The intention is essentially to educate the future elite. Admission is highly selective, with this process based solely on merit, not geographical location. The CPGE programmes are national, with content determined by both the national government and the university admissions exams to the *Grandes Écoles*. Assessment throughout the programme is not externally determined; rather, individual teachers have full autonomy. Students must maintain high results to achieve admission to the second year of the programme.

The *Brevet de Technicien Supérieur*, or BTS is a two-year advanced technical training course for advanced technical vocations, such as trilingual secretaries or electricians. Like CPGE, these courses are conducted within the high schools of major cities and admission is dependent on student performance in upper secondary school. Assessment during the course is also the responsibility of individual teachers. The diploma received by students on completion is normally the highest qualification required to enter the labour market in their field of specialization.

Nevertheless, some students do continue to further studies at university level on completion of the diploma (Ministère de l'Enseignement Supérieur et de la Recherche, 2012).

The *Institut Universitaire Technologique*, or IUT are institutes of technology offering two-year training courses for high school graduates prior to university study. These institutes are attached to major universities. While they are able to autonomously determine the courses they offer, these IUT institutions follow nationally imposed guidelines regarding curriculum and assessment, and they are subject to auditing and approval by the national government every four years. Diplomas are provided to students on completion and are the necessary qualification for entry to advanced technical professions in their field of specialization. Like BTS graduates, many IUT students will choose to continue their studies at university level (Ministère de l'Enseignement Supérieur et de la Recherche, 2012).

Since 2003, French universities have operated in accordance with the European LMD system, that is, the *Licence-Maîtrise-Doctorat* (Bachelors, Masters, PhD) qualifications framework. Essentially, students begin their university studies at Bachelor level through a three-year standard programme of coursework. If they continue their studies, they move on to a two-year long Masters programme, after which they can choose to enrol in a three-year PhD doctoral research programme. French universities are subject to greater external control than their Australian counterparts. In France, universities follow national guidelines specific to each discipline area regarding programmes of study, content, contact hours, and the balance between small tutorial groups and lectures. While each university retains control over programme design, like the IUTs, each course plan must be approved by the National Ministry of Education and Research every four years (Ministère de l'Enseignement Supérieur et de la Recherche, 2012).

The coverage of STEM throughout French tertiary education

Les classes préparatoires (CPGE)

The CPGE programme of preparatory classes provides three alternative study specializations:

- **Science:** This track prepares students for admission to tertiary level engineering schools (*Grandes École d'Ingénierie*).
- **Business:** This track prepares students for admission to tertiary level business schools (*Grandes École de Commerce).*
- **Literature:** This track prepares students for admission to tertiary level courses at either *l'École Normale Supérieure* in both Paris or Lyon, or to *Sciences Po* in Paris. (*Sciences Po* is the Paris Institute of Political Science.)

Both science and business majors include a strong mathematics component, although the teaching of science subjects is quite limited. Literature students, however, study only the humanities and social sciences, including subjects such as French literature, philosophy, history, geography and languages, both modern and archaic (Latin, ancient Greek).

Brevet de Technicien Supérieur (BTS)

There are 88 different specializations on offer for students to choose from in the BTS programme. Among these are four STEM-related options: Chemistry, Biotechnology, Nuclear Environment and Optical Engineering. Students looking to become chemists are called to develop expertise in the elaboration of substances, as well as the analysis of chemical products. A solid curriculum in mathematics, physics and computer science provides grounding for their training (Ministère de l'Éducation Nationale de la Recherche et de la Technologie, 1997). By contrast, training in Biotechnology concentrates mostly on the study of molecular biology, analytical biochemistry, microbiology, laboratory sciences, mathematics and computer science, though this last topic is adapted to the field of biotechnology (Ministère de l'Éducation Nationale de l'Enseignement Supérieur et de la Recherche, 2007). In the Nuclear Environment specialization, students focus both on the analysis and the organization of activities, and on modeling methods and technical choices within a nuclear environment (Ministère de l'Éducation Nationale de l'Enseignement Supérieur et de la Recherche, 2011). Finally, Optical Engineering students are given the option to specialize in Photonic (physics) or Instrumental Optical. Both of these require a strong physics background (Ministère de l'Éducation Nationale de la Recherche et de la Technologie, 1998).

Institut Universitaire Technologique (IUT)

Students in this programme may choose to train for industrial or service sector vocations. Training for industry can include some science education, with options provided to study chemistry and biology, or electronics, computer sciences and mechanics, or public works, energy and security. The first of these is very straightforward and composed of chemistry and biology courses. The second is, however, more focused on electronic systems, material sciences, physics, computer sciences, industrial and mechanical engineering. The last one concentrates on the environment, security, civil and energy engineering (Campus France, no date).

Universities

Programmes and courses relevant to all STEM fields are on offer in universities across France. Of these fields, engineering is the most recently added to university level study. Throughout the twentieth century, the most common pathway to a career in engineering was through the preparatory programmes in major high schools described above as CPGE programmes from which students could compete for entry to prestigious tertiary level engineering schools. However, in the last decade, universities have begun to provide competitive alternative pathways to engineering studies.

Enrolment in STEM fields at tertiary level

Enrolments in tertiary level STEM studies in France are slightly above average among countries of the European Union (EU). From 24% of all enroled students in the fields of science, mathematics, computing, engineering, manufacturing or construction at ISCED level 5 and 6 in 2004, the percentage of students in these tertiary level STEM studies in France increased to 25.6% by 2010, compared with 25% for an average of 27 EU countries (see Figure 4, A). However, what is most noteworthy here is that by 2009, France was retaining 4.2% more of these students to graduation in the fields of mathematics, science and technology than the average of countries in their region (see Figure 4, B).

Further comparative international data on enrolments in, and graduations from, STEM fields illustrate France's comparative success in attracting and retaining students in these fields at tertiary level. World Bank provides data for Australia and France that can be compared here, with these figures showing that the percentage of all ISCED level 5 and 6 tertiary graduates from fields in science, engineering, manufacturing and construction fell from around 30% in 2000 to 26% in 2009 (World Bank, 2012, 2012a). While Australia's figures also fell, the national averages are lower overall, from just over 19% of graduates in 2000 to 16.6% in 2009 (World Bank, 2012, 2012a). (Note that a significant proportion of these students in both Australia and France are graduating from university.) Figure 5 below illustrates this comparison by field of study. The Organisation for Economic Cooperation and Development (OECD) also collate data, finding that while France has a higher proportion of students in STEM fields of study than Australia, both countries exceed the OECD average. In 2010, 2 219 students graduated from science-related tertiary study among 25-34 year-olds, per 100 000 of this cohort in employment (OECD, 2012a). The figures were 2 776 in France, and only 1 944 employed 25-34 year-old science-related tertiary graduates per 100 000 25-34 year-olds employed on average among OECD member countries (OECD, 2012a) (see Figure 6 below).

Figure 4: The proportion of students enrolled or graduating from STEM and STEM-related fields at ISCED level 5 and 6 in France, 2002-2010. Data sourced from Eurostat (2012c, 2012f).

A: The percentage of enrolled students in the fields of science, mathematics, computing, engineering, manufacturing or construction.
B: The percentage of graduates from the fields of mathematics, science and technology.

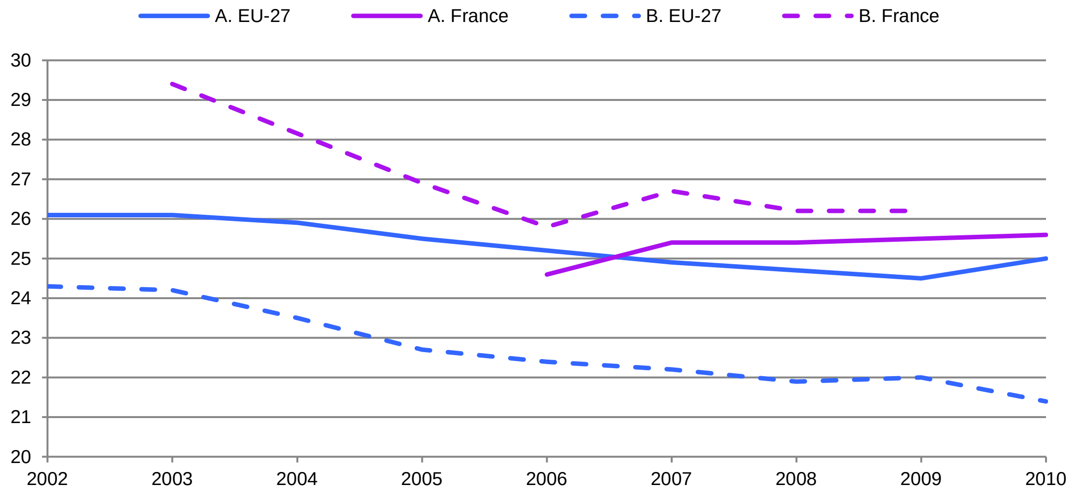


Figure 5: The percentage of ISCED level 5 and 6 tertiary graduates by STEM field for Australia and France. Data sourced from the World Bank (2012, 2012a).

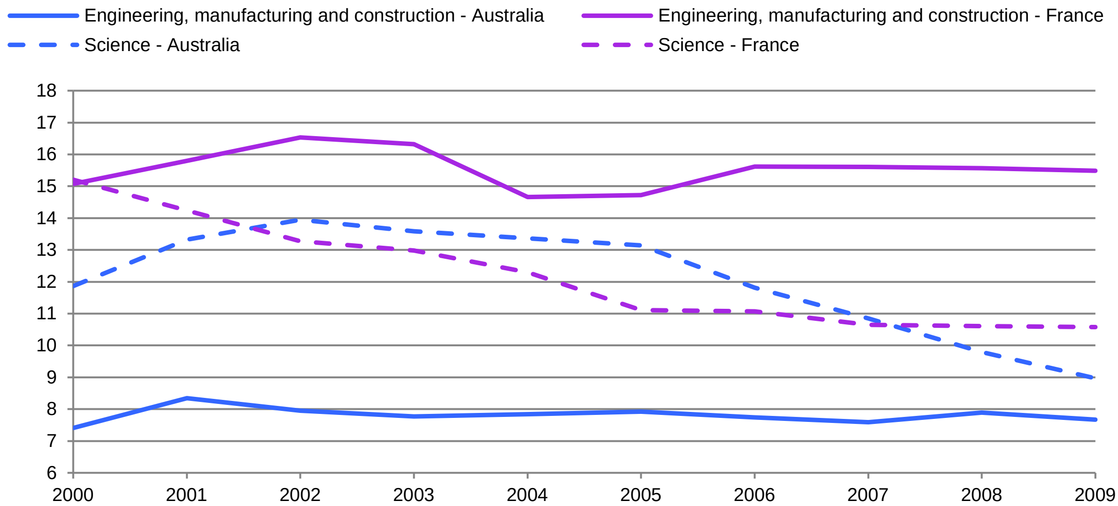
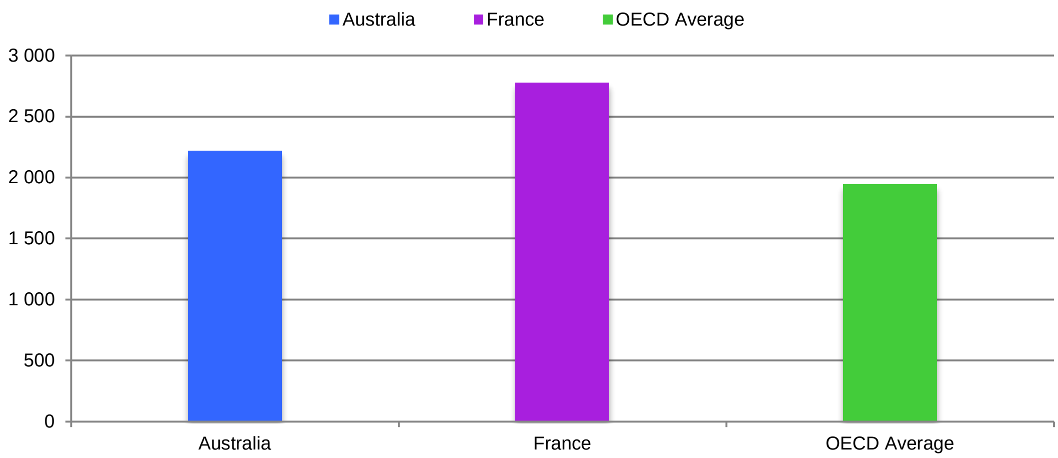


Figure 6: The number of science-related tertiary graduates in 2010 among 25-34 year-olds in employment, per 100 000 of this cohort in employment. Data sourced from OECD (2012).



In 2011, the majority of STEM students were attending universities (59.2%). Engineering schools and IUTs (institutes of technology) followed this with 12.3% and 7.4% of enrolled tertiary students, respectively (Ministère de l'Éducation Nationale, 2012b:173) (see Figure 3 above for an illustration of the numbers enroled). Engineering figures are boosted by the 6.6% of tertiary students enroled in the same year in CPGE programmes in preparation for entry to engineering schools (Ministère de l'Éducation Nationale, 2012b:173).

- *Mathematics*

At tertiary level, the only way to study mathematics is through a dedicated Bachelor degree within a university or as part of an engineering programme at either a specialist engineering *Grandes Écoles* or university. University courses are varied. Students have the option of short or long programmes, fundamental or applied mathematical sub-disciplines, normally increasing specialization as students progress. Students are encouraged to pursue their study of mathematics at Masters level or through an integrated engineering programme in order to increase their chances of employment.

- *Sciences*

The term sciences is used here to comprise the domains of biology, environmental sciences, physics and chemistry. Biology and environmental studies are available for study through technical programmes towards a BTS. These courses are generally two years in length, and further study is usually required to secure employment or career advancement. Bachelor and Masters level programmes are offered by universities in these fields.

Universities also offer a variety of Bachelor and Masters level programmes for the study of areas within the domains of physics and chemistry. After completion of the Scientific Baccalaureate at upper secondary level, students can choose between preparatory CPGE classes in physics and chemistry, known as *Physique* and *Chimie* (PC), or in physics, chemistry and engineering, known as *Physique-Chimie-Science-Ingénierie* (PCSI). Those who pass the entry examinations to the *Grandes Écoles d'Ingenieurs* on completion of CPGE, undertake engineering studies at one of these prestigious tertiary schools. Students may also choose to attend a university programme on completion of the CPGE, but most will need to complete both Bachelor and Masters level programmes here in order to increase their competitiveness in the labour market and secure employment after graduation.

- *Engineering*

Most engineers in France have been trained via the CPGE system. The high level of teaching in the Science strand of these programmes ensures students develop a solid grounding and high level of competence in the domains of mathematics, physics and chemistry. However, the downside of this training is that it is almost entirely theoretical and academic, lacking in professional experience. After the Science CPGE course, a great number of engineering schools are available to students, allowing them to specialize for their career. These large specialized schools can add this element to students' training. The three most prestigious French engineering schools – *École des Mines*, *Polytechnique Paris* and the *École Centrale* – present a more integrated curriculum of study over three years. Study is free of charge and students receive a monthly remuneration throughout each year of study. Students whose CPGE results do not qualify them for entry or those who choose instead to enroll in a more specialized engineering school (with a focus such as construction or telecommunications) can also find schools that integrate theoretical study with professional experience, but often need to study there for a further five years. Remaining institutions tend to provide more general training, with specialist courses offered only in students' final year of study. All of these institutions deliver the same course type, namely, a degree in engineering.

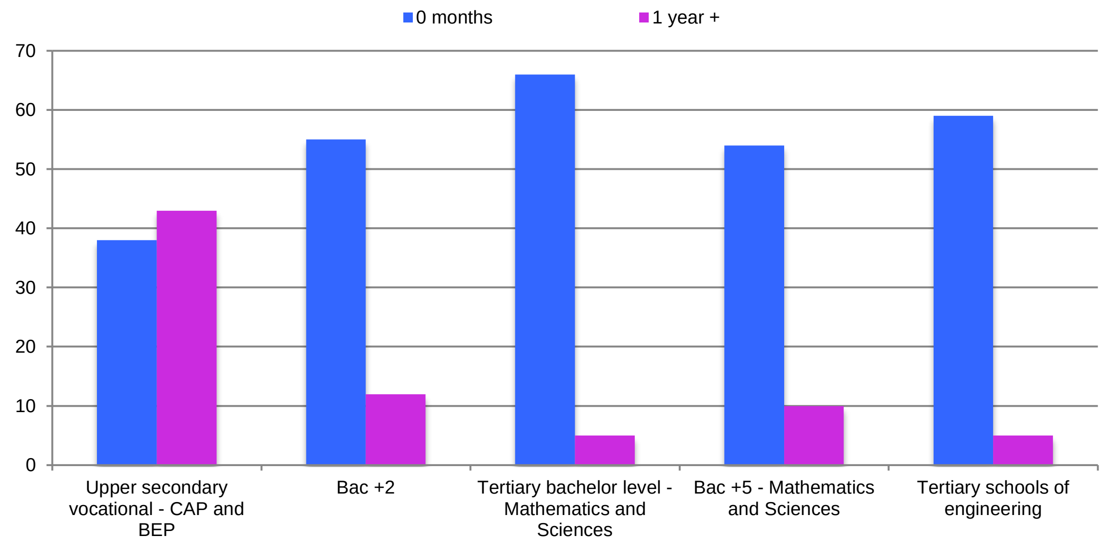
- *Technology*

Students who would like to pursue a career in computer sciences and systems, or technological development in France must follow the same path as engineering students, specializing eventually in their preferred field. Alternative pathways exist through two-year programmes at an IUT or BTS. Following this route allows individuals to become technicians in the domain, but restricts their ability to progress their career later. However, a significant number of these technical graduates eventually pass entry examinations to the *Grandes Écoles d'Ingénierie* or engineering schools, obtaining more advanced qualifications. In fact, 14.1% of BTS students in the academic year 2011-2012 followed this path to further study in engineering schools across France (Ministère de l'Éducation Nationale, 2012b: 183).

STEM graduates in the French labour market

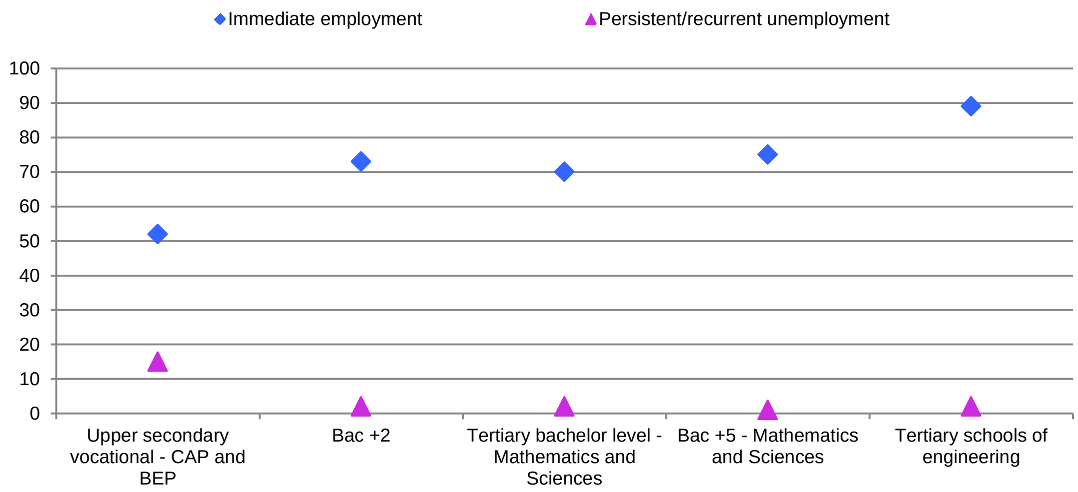
Graduates from higher levels of education have a labour market advantage, that is, they tend to enter the labour market more quickly and can more easily maintain stable employment. Young people in France were particularly influenced by unemployment in the wake of the financial crisis. According to a study conducted in 2010 on 2007 graduates, it is the least qualified that experience the highest unemployment rates in their first year as young professionals (Céreq, 2012). University students graduating in 2007 from five years of study in mathematics and science degrees have not been spared. Figure 7 below shows a 10% unemployment rate for at least one year for these students. It is, in this respect, quite surprising to observe the very small unemployment gap between those Bac +5 graduates and Bac +2 students, who experienced a 12% unemployment rate (Céreq, 2012:23). The expression Bac +5 refers to students who have pursued five years of study at university (here in Mathematics and Sciences degrees) after the completion of their upper secondary Baccalaureate (general or professional), and allows a distinction to be made from the students who study at Schools of engineering, as their studies also last 5 years. Similarly, Bac +2 describes those students who have undertaken two years of tertiary study after obtaining their general or professional Baccalaureate in upper secondary and, as such, refers to BTS and IUT students whose tertiary programmes run for two years.

Figure 7: Percentage of time spent in unemployment by 2007 graduates by course. Data sourced from Céreq (2012).



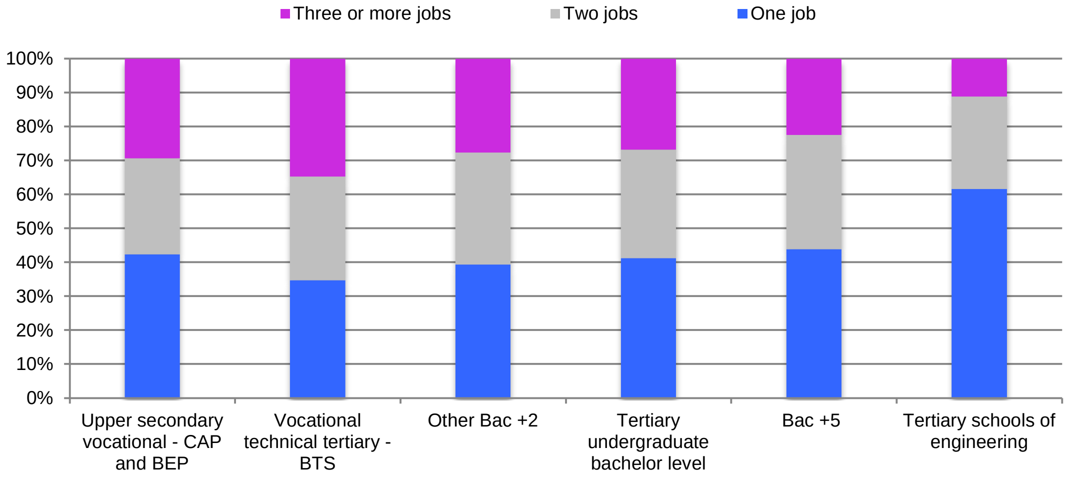
The benefit of higher education can be seen in an examination of graduates' access to employment. Access to the French labour market has become increasingly complex and demands that individuals possess more skills and higher qualifications than ever before. The level of educational achievement is key to an applicant's success and highly determining in a graduates' ability to find timely employment. In 2010, 75% of Masters' graduates experienced immediate employment, compared with 73% of graduates from the Baccalaureate +2 years of tertiary education, 70% at the Baccalaureate level and 52% from vocationally directed upper secondary programmes, BEP and CAP (Céreq, 2012:35). It is interesting to note that students who have graduated from vocational or professional degrees tend to have easier access to employment than more industrial and tertiary education graduates. Persistent or recurrent unemployment is, however, almost non-existent for all tertiary education graduates, but fairly common for vocational education graduates (15% of graduates in 2007 had experienced this by 2010).

Figure 8: Percentage of 2007 graduates having experienced immediate employment or persistent/recurrent unemployment in 2010. Data sourced from Céreq (2012). Note: The term Bac is short for Baccalaureate and Bac + number refers to the years of study after obtaining the upper secondary Baccalaureate; Bac +2 comprises both BTS and IUT graduates.



Fast access to, and stability in, employment is a luxury that appears to have been available to only graduates from engineering. The 2010 national study of the 2007 cohort of graduates shows that unlike the 61% of engineering school students who maintained their first job, more than half of the 2007 graduates from other courses changed jobs at least once during this first three years in the labour market (Céreq, 2012:39). One third of the graduates from vocational and professional courses had experienced at least three different jobs in the three years after leaving education (see Figure 9). Bac +2 graduates seem to have had little difficulty getting their first job. One may argue that those figures reflect the context of employment precariousness triggered by the 2008 economic crisis that French citizens, and mostly young professionals, suffered from rather dramatically.

Figure 9: Percentage of 2007 graduates who have since been employed in one, two, three or more different professional jobs since graduation, by level of education in 2010. Data sourced from Céreq (2012). Note: The term Bac is short for Baccalaureate and Bac + number refers to the years of study after obtaining the upper secondary Baccalaureate.



Attracting students to study STEM fields in France

What problem?

An increase in the number of researchers, particularly in STEM-related fields, is an economic priority for recovery, stability and growth in the coming years. However, in the past couple of decades, developed countries around the world, including France, have experienced a significant decline in the proportion of students choosing these fields of study and pursuing research pathways (European Communities [EC], 2008, 2004; OECD, 2008). Despite dramatic increases in the number of students attending university over the past twenty years, the proportion of tertiary students choosing to study STEM subjects and programmes has declined over this period, by up to 50% in some disciplines, including physics, mathematics and chemistry (EC, 2008). While it must be acknowledged that France has made some progress to stabilize these figures in recent years, the problem persists (EC, 2004; OECD, 2008). It is important to note that the issue has its origins prior to university entrance. Student attitudes to study in these areas and their understanding of both their own abilities in these fields and the nature of such careers, shape their choices much earlier. A particularly significant decline in graduates majoring in science and technology at upper secondary level over the last 10-15 years can be observed, with the most dramatic changes occurring through the late 1990s and early 2000s (OECD, 2008).

Pathways to STEM: Attitudes to training

The choice to major in science during upper secondary has always been thought of as the road to academic and professional success. It is generally understood that graduates of the S strand of the *Baccalauréat Général* have all doors open to them. These young people can normally be distinguished by their favourable social condition and their excellent grades. Indeed, four out of ten of these have teachers, well-ranked *fonctionnaires*, or corporate executives for parents, who have themselves pursued education for longer than the average citizen (Inspection Générale de l'Éducation Nationale, 2007:10). In addition to their social status and strong school performance, graduates of the upper secondary S strand tend to possess high ambitions for at least 3-5 years of study at the tertiary level. However, it is important to note that they are often not driven by a passion for the sciences. More than a profound interest in scientific subjects, it is the ambition to undertake a professionally successful and financially rewarding career that prompts most of these students to enrol in this strand of the *Baccalauréat Général* programme (Inspection Générale de l'Éducation Nationale, 2007). The National Ministry of Education is, of course, concerned by this, but further the scientific community links this with the persisting gender imbalance in engagement in mathematics and sciences at secondary and tertiary levels. Female representation in STEM fields has increased over recent years, but remains low.

A career in science is seen as highly desirable in French society. Engineers and other professionals in the scientific field are important actors in the domain of innovation and France's economic and industrial competitiveness. In spite of having some of the highest rates of enrolment in STEM fields throughout education levels among EU countries, a thoroughly economic perspective would argue that there remains a lack of scientific and engineering experts in France. The issue lies in students' choice of tertiary level education. In other words, taking the long road or the short one (Fondation Res Publica, 2012). Once graduated from the most grueling upper secondary programme, these students will need to pursue 5 years or more of further education in engineering schools or universities. Graduates from the *Baccalauréat Professionnel* who chose the scientific orientation of this programme in upper secondary can also pursue a career in science. They may only need to complete a two-year course to do this and so it is very attractive to students who want to get into the labour market sooner rather than later. The problem is that the lower level of expertise they gain through this study path will not prepare them for the same high-level positions of their peers in the longer university pathway. Consequently, these shorter, more technical courses have been identified as a hindrance to the "production" of scientific experts in France and, as such, have recently become an object of debate (Fondation Res Publica, 2012).

Factors thought to influence student motivation and performance in STEM fields

Determining factors of student motivation to select, and performance in, STEM fields of study have been the object of sound analyses at the European level, particularly vis-à-vis mathematics and science. Research reveals a combination of influences including student factors – home background, attitudes and self-efficacy – and external factors – the nature of the learning environment and teaching styles experienced during early studies within these fields. Unfortunately, it is difficult to determine the extent to which the following information applies to France, as the country rarely participates in regional surveys or reports on this theme.

Students' background

The international evidence supports a significant correlation and causal connection between features of a students' home background and their attitudes and performance levels exhibited at school. Both large-scale standard international tests of school student abilities in STEM areas have identified a strong relationship between student achievement in mathematics and science, and their background. These testing programmes measure numerous economic, social and cultural factors with which to compare performance data, such as access to books at home, languages spoken in the home, parental income and occupation. The Programme for International Student Assessment (PISA) is one of these major international tests. Administered by the OECD, PISA measures scientific and mathematical literacy levels, in addition to reading literacy, among 15 year-olds in more than 70 countries. The latest round of PISA testing conducted in 2009 found that compared to a French student from an average background, one of their peers within the top seventh of the calculated socio-economic index is likely to achieve more than 50 score points on the test, equivalent to nearly an extra year and a half more schooling. Eurydice (2011a) reports that 16% of variation in student performance among EU countries can be explained by socio-economic factors from a students' home background. Disadvantaged students tend to spend less time studying than their more advantaged peers and make pathway choices that present little opportunity to focus on science or mathematics. It seems that learning time prior to secondary school level should, therefore, be used to enhance disadvantaged students' interest and performance for these fields. Although the correlation between student achievement and student background seems fairly obvious, it should be noted that disadvantage is not the only contributor to poor performance.

Positive attitudes towards mathematics and self-confidence in learning have been shown to influence student achievement as well. PISA results have highlighted the importance of students' enjoyment of learning and their self-efficacy or self-belief in their abilities as similarly associated to overall performance (Eurydice, 2011a). These motivational aspects thus influence students' choice of track, thereby also shaping their post-secondary education and career choices.

Finally, teaching practices have also been identified as a determining factor of student motivation. The nature of tasks and exercises given have a great impact on whether students feel challenged and motivated to invest effort in the mathematics and science learning process. Indeed, studies have shown that students' positive attitudes towards those subjects are principally related to the nature of the teaching approach adopted (Eurydice, 2011a). Engaging, diversified and connected teaching methods should provide students with the understanding and the belief that the knowledge acquired will be of good use in their everyday life. A supportive learning environment should therefore be established in order to enhance students' intrinsic motivation. In such an environment, students should feel that their opinion is valued and enjoy engaging with their peers about mathematical and science-related topics.

Gender balance in STEM fields

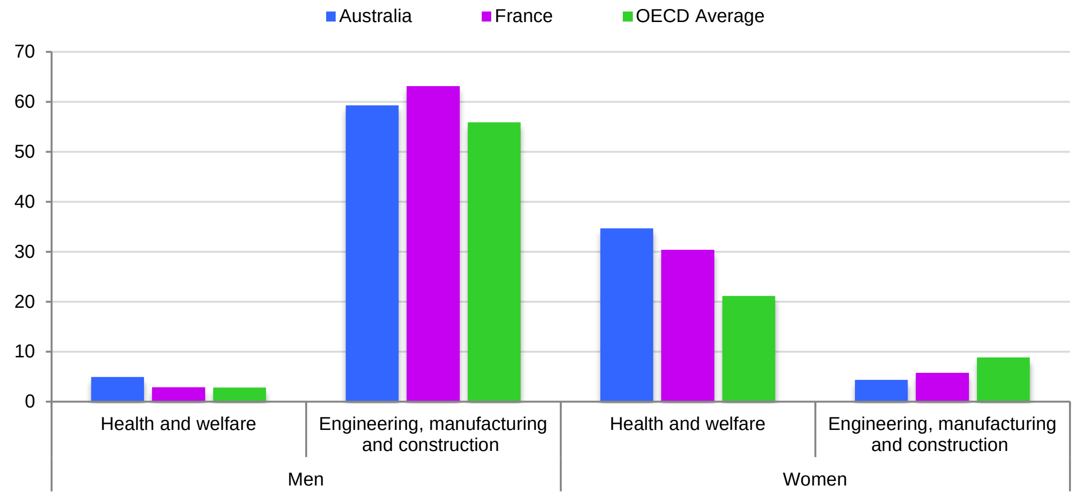
Women are under represented in scientific and other STEM-related professions across Europe (Reust-Archambault et al., 2008; EC, 2008). In the mid-2000s, 30% of those researchers employed across EU-15 countries were women, in contrast with the overall 44% of employed persons and 46% of all professionals who were women (Reust-Archambault et al., 2008). France is not excluded from this (EC, 2008). Fewer women, only 32%, are employed as scientific researchers in the public system (universities and research institutes/centres) in France (EC, 2008). Their promotion to senior positions and inclusion in selection and decision-making bodies are also less than equitable, with women accounting for only 24% of such appointed committee members in France (EC, 2008). Furthermore, less than 12% of university presidents are women. The under representation of women across Europe is particularly marked in engineering and technology fields (EC, 2004). While there is an economy wide gender pay gap that persists in France, the fixed salary schedules in academic research remove this issue for STEM researchers. However, with more women in lower grade positions, their salaries are in practice lower.

There are a myriad of causal factors for this discussed in the literature from cultural understandings of which occupations are for which gender, to poor career outlook in these fields (Reust-Archambault et al., 2008; EC, 2008). The EC further argues that, in France in particular, there is a lack of 'conscience of a gender problem' (EC, 2008:48). Surveys of researchers have found that there is no recognition of any problem or discrimination. Furthermore, there is a distinct absence of data on this issue, particularly in France, which, if collected, could raise awareness and allow the situation and any progress to be monitored (EC, 2008). Apparently, within the European region, progress on the issue of equality for women in STEM fields of employment is particularly slow in France. Strong support for this issue built up around the year 2000, with some strategies implemented around this time, but more recently, the EC (2008) noted a decline in interest. However, progress does continue. The main research organization in France, known as the CNRS has a stated mission to improve the status and conditions of employment for women in research, including within STEM fields. This promising mission has so far been fulfilled by the CNRS having 'financed high quality research on the history of women in the CNRS, on career problems, on evaluation processes to understand the mechanisms that handicap women (and men)' (EC, 2008:48). Moreover, several years ago, equality legislation was passed for professional equality that required the balanced composition of males and females on committees and other decision-making bodies within the French civil service. However, this legislation exempts higher education and research, an oversight that is yet to be rectified (EC, 2008).

Steering the career ambitions of more young women towards the STEM fields continues to be a central objective of the French National Education Ministry. Their efforts here are not in vain, with progress slowly being made. The enactment of egalitarian gender policies in this area began in the late 1980s, with agreements such as the bilateral convention signed between the Education Ministry and the Ministry of Women's Rights (1984-1989), which aimed to encourage the diversification of girls' professional choices. Furthermore, the preferences of female students in upper secondary school can be seen to have changed, with the number of girls choosing the science major track in the *Baccalauréat Général* programme having tripled over the past twenty years to reach 46% in 2011 (Ministère de l'Éducation Nationale, 2012b:115). In addition, girls tend to achieve higher results in the science major of this programme. Female students have exhibited a 91.1% success rate in comparison with only 87% for boys. As many as 31% of these girls gain honours, while only 25% of their male peers achieve this level (Stevanovic, 2012:4).

In spite of improvements made by girls in upper secondary science studies in recent years, gender patterns can still be observed. Figures from 2008 illustrate the tendency of girls to choose life and Earth sciences (58% girls), rather than physics and chemistry (47% girls), mathematics (40% girls), or engineering (only 14% girls) (Ministère de l'Éducation Nationale, 2012b:4). Professional gender stereotypes continue to influence student decisions, with girls more inclined to envisage themselves working in traditionally more 'feminine' professions, rather than the still male-dominated areas such as engineering. The proportion of girls in the professionally and vocationally oriented courses illustrates this phenomenon. In 2011, 89% of students who chose the BEP courses were female, in comparison with the only 43.6% of CAP students (courses leading to manual labour and construction jobs). Similarly, girls outnumbered boys (55.6%) in final year tracks, choosing to major in laboratory sciences (the STL track), compared to the industrial sciences (the STI track) in which there were only 11.3% girls (Ministère de l'Éducation Nationale, 2012b: 107, 115). OECD data confirm the gendered pattern of subject choice for vocational students in upper secondary education. Male students tend to choose tracks that take them towards the engineering, manufacturing and construction sector, while female students gravitate towards health and welfare (see Figure 10 below for more detailed comparison of Australia, France and OECD vocational graduates in these fields). Gender differences in achievement in mathematics and science throughout school level education are minimal in France. Studies show that, on average, boys and girls have similar competences in mathematics throughout most of their school years (Eurydice, 2011b). Where any differences occur, female students are inclined to perform at a slightly lower level in mathematics and physics than their male peers, but higher in more language rich areas of science, such as identifying scientific issues and explaining scientific phenomena (Eurydice, 2011a).

Figure 10: The distribution of upper secondary vocational graduates, by field of education and gender in 2010. Data sourced from OECD (2012).



The gendered pattern of subject choice observed at secondary level continues into tertiary education. Female graduates of the upper secondary *Baccalauréat Général* science track are more likely to choose fields such as medical studies (61.2%), pharmaceutical studies (66.9%) in 2008 and natural sciences (59.5%) in 2009, which have become more feminine careers (Ministère de l'Éducation Nationale, 2012b:6). Further data has been charted below to illustrate the gendered engagement of students in STEM studies at tertiary level. Eurostat data show that nearly 30% more males in France graduated from tertiary studies in mathematics, science and technology fields in 2009 (see Figure 8). While the French figures are better than the average of the 27 EU countries included in this dataset, there clearly remains a significant issue. The gender disparity is also apparent in OECD data illustrated in Figure 12, through the number of male and female science-related tertiary graduates in 2010 among 25-34 year-olds in employment, per 100 000 of this cohort in employment. For both sexes, France engages more students in tertiary science than Australia, with both countries sitting above the OECD average. However, the strong gender divided pattern remains consistent. Similarly, World Bank data on ISCED level 5 and 6 tertiary enrolments in science, engineering, manufacturing and construction fields highlight the disinclination of females to engage in any of these STEM-related fields through tertiary education in both Australia and France (see Figure 13). As few as 14% of female tertiary enrolments are in these fields, compared with 25.5% of all tertiary enrolments in France. In Australia, these same figures are lower – 9.5% and 19% respectively (see Figure 13). The trend data on these indicators shows this pattern becoming increasingly significant throughout the past 10 years.

Figure 11: The proportion of male and female graduates from ISCED level 5 and 6 study in the fields of mathematics, science and technology in France, 2002-2010. Data sourced from Eurostat (2012a, 2012b, 2012d, 2012e).

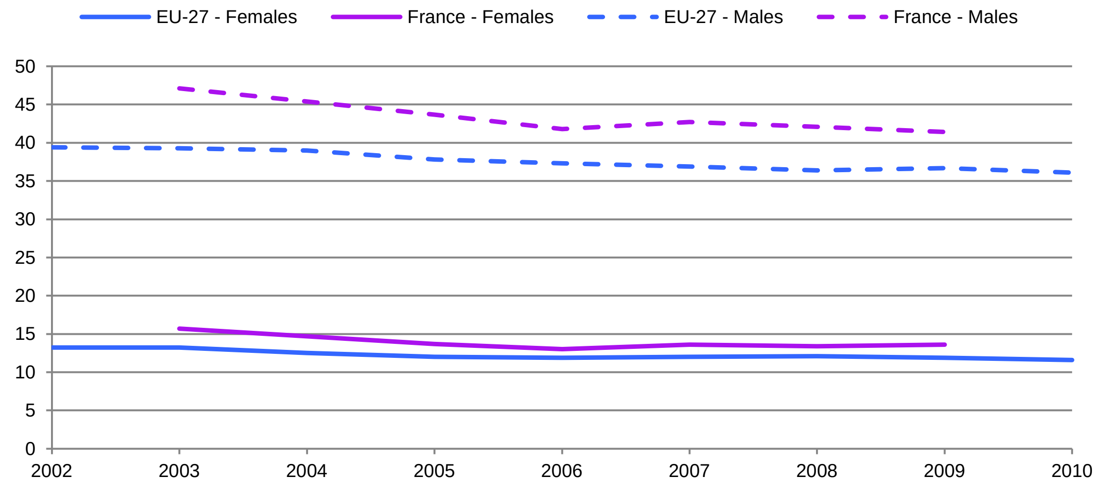


Figure 12: The number of male and female science-related tertiary graduates in 2010 among 25-34 year-olds in employment, per 100 000 of this cohort in employment. Data sourced from OECD (2012).

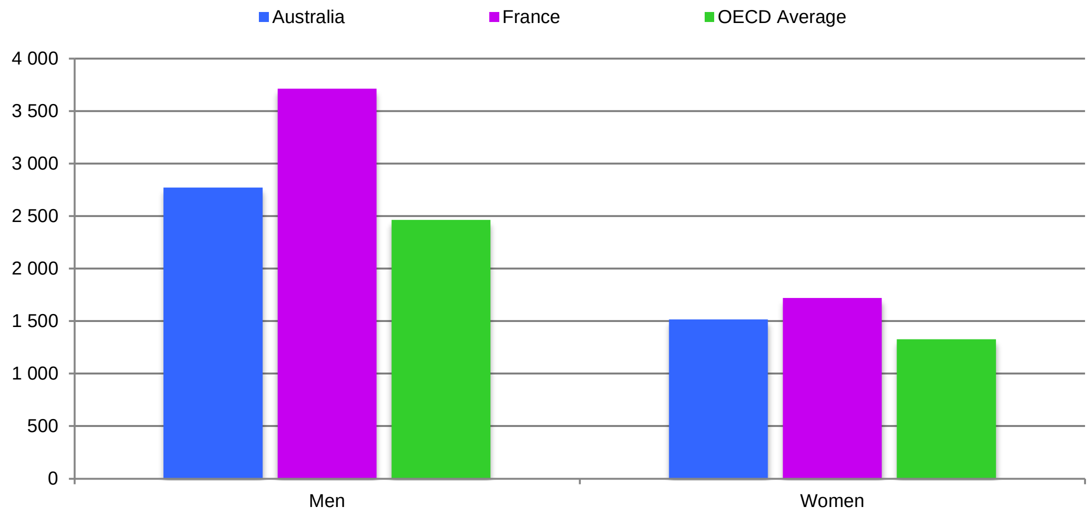
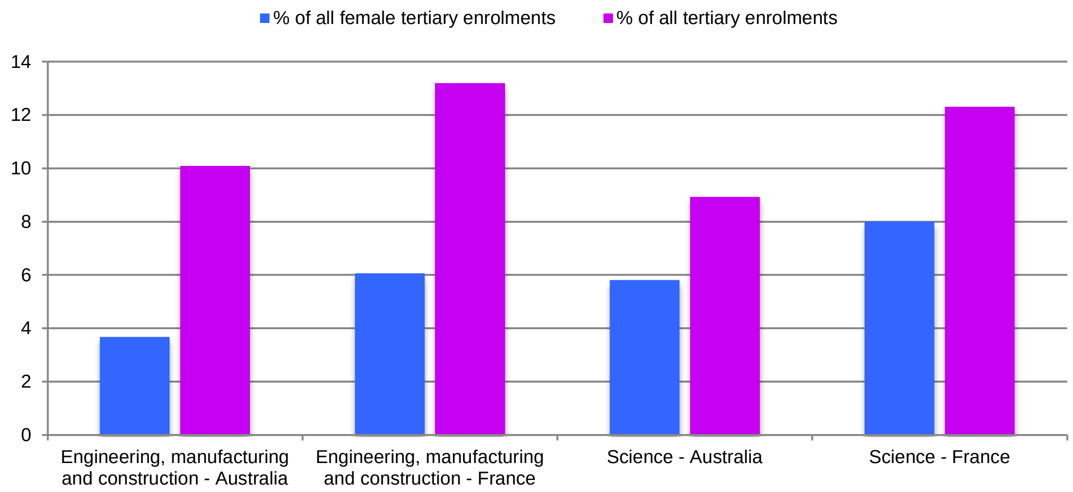


Figure 13: The percentage of ISCED level 5 and 6 tertiary enrolments by STEM field – female versus all enrolments in 2010. Data sourced from World Bank (2012b).



On a more positive note, national data in France show that between 2011 and 2012, the percentage of females enroling in tertiary level engineering increased slightly more than 5% above the consistent rate of around 20% since 2000 (Ministère de l'Éducation Nationale, 2012b:5). Nonetheless, this figure remains particularly low for significant change to be claimed. Increasing the participation of women through enrolment in STEM-related education remains a persistent and significant challenge.

Strategies to enhance STEM education

In the classroom strategies

Within the context of French education, any policy changes or programmes devised to enhance STEM engagement must not only be innovative and evidence based, but must also be congruous with the existing education system. Both school and tertiary level education are well prescribed, for example, governments stipulate the time devoted to teaching in each discipline, set curriculum content and national assessments that together limit and defy the scope for creativity in the classroom. Nonetheless, there are reforms and efforts in progress that will be discussed here. Due to a lack of available information about the fields of engineering and technology, mathematics and science will be the focus.

Mathematics curriculum

The primary and lower secondary (ISCED levels 1 and 2) mathematics curricula were revised as part of reforms conducted through 2007 and 2008. The content of the newer curriculum was thinned in order to allow teachers to place greater emphasis on student development of problem-solving and procedural skills. In contrast, the aforementioned 2010 reforms to the upper secondary system brought additional content, such as mathematical algorithms and probabilities, to the curriculum at this level but as well as greater focus on cross-curricular links, such as the interaction of mathematics with technology, philosophy and science (Eurydice, 2011a).

The recommended proportion of time devoted to each component of the mathematics curriculum in primary and secondary school can be used as a proxy to explain the relative importance of this subject in relation to others. Teaching time in European countries is organized differently throughout the various school levels, with a significant increase during lower secondary. The Eurydice (2001a:39) edition on mathematics education in Europe reports that mathematics instruction should account for between 15% and 20% of all contact time at primary school level, increasing thereafter. However, the same report shows that, in France, the percentage of hours dedicated to mathematics education is equal both at primary school (17.2%) and secondary school (17.4%), resulting in total teaching time dedicated to this curriculum area of nearly 20%. This finding is consistent with the observation made by Dorier et al. (no date) that, even in the *Baccalauréat Général* Scientific (S) track, mathematics instruction does not occupy more than 20% of the total contact time for teaching all subjects. It would seem from this evidence that mathematics is not a priority as a stand-alone discipline, but is addressed instead through other scientific and arts disciplines. No mention of the effectiveness of this was identified in the literature.

Science curriculum

There has been no substantial revision to the science curriculum in France in recent years. However, a formal strategy for the promotion of science and technology was conceived in March 2011. Importantly, the strategy is intended to build synergies among current programmes, rather than creating new ones. Its objective is, more specifically, to improve students' interest in these subjects at ISCED level 2, by teaching science as an integrated subject, promoting scientific studies and encouraging all students to participate in external activities and competitions. The strategy also aims to promote careers in these fields to students at ISCED level 3, with a particular focus on female students, although strangely this is not a goal of any prior educational level (Eurydice, 2011b.).

The balance between teaching science as an integrated general science topic or as distinct sub-disciplines within French schools is an ongoing national debate. While resolving this issue is not the purpose of this review, it remains an important point to mention. Both forms of science teaching can be found in European countries. France integrates the sub-disciplines through teaching general science at ISCED level 1, beginning to tease these out to the separate-subject approach during ISCED level 2, completing this process throughout upper secondary at ISCED level 3. It should be noted that science teaching here includes technology. European countries suggest that science subjects within lower secondary schools cover everyday technological applications of scientific phenomena (Eurydice, 2011b). This connection between scientific learning at school and students' everyday life experiences is particularly important as it increases their motivation to engage in study in these fields, and often results in higher academic performance.

National testing

France introduced national tests of mathematics and science at primary school grades 2 and 4 in 2009. The test is conducted in accordance to the *Socle Commun* of competences and is intended to identify low performers. Traditional forms of classroom-based assessment of student knowledge and skills persist particularly strongly in France, with many teachers relying on written examinations to ascertain students' grasp of the core set of common knowledge and skills. The *Socle Commun* aimed to encourage teachers to move away from these traditional assessment techniques and innovate in this area.

The results of national tests in France are not only used by teachers, but also by the Ministry of Education in order to detect learning difficulties in any subject and inform future policies and better teaching practices. Indeed, in 2010 the Court of Auditors has published a report entitled "National education and the objective of success for all pupils" based on field studies and interviews with practitioners and experts. The report advocated the need to improve the French system's efficiency to achieve greater equity. Moreover, it stated that the tools previously put in place to tackle low performance in mathematics and science had not produced satisfactory outcomes. It has been recommended that teachers develop consistent practices, set realistic goals and follow a more rigorous in-service training (Eurydice, 2011a). In light of this evidence, establishing a national monitoring strategy could prove beneficial to the improvement of the French education system.

A remedial programme was introduced to assist low performing students identified in the recently introduced national tests. Students are required to attend small group support classes delivered by their teacher for two extra hours each week. These teachers were provided with professional development to enable them to better support individual student learning through this personalized and remedial approach. During this extra class time, low performing primary students in science and mathematics participated in the development of individual learning plans, known as *Programme personnalisé de réussite éducative* (PPRE). These were based on a small number of objectives in mathematics and science and designed to address the individual weaknesses of students through differentiated instruction and small group instruction. Once students have progressed in line with the schedule of competence, the *Socle Commun*, they can stop attending the extra classes.

National and municipal initiatives

Many initiatives have been pursed at the national and the municipal level in France to enhance STEM education in and outside of schools. They primarily target lower and upper secondary students, however a few organisations have also made the awakening of small children's curiosity for sciences a priority through various discovery and learning programmes.

Sciences à l'école

The French Ministry of Education is responsible for many aspects of science education, from the development of curriculum to the administration of short term scientific projects. Sciences at School, a scientific programme known as *Sciences à l'école*, is the most popular project, and was jointly launched by the Ministry of National Education and the Ministry of Higher Education and Research in lower and upper secondary schools. The programme has attracted high-level researchers and professors in innovative school and higher education teaching to chair the project steering committee. The project has been funded by the government and the industry foundation *C.Genial* since 2004. *Sciences à l'école* encourages the elaboration of scientific projects carried out in workshops and clubs which take place as extra-curricular activities outside of school hours, in order to boost support for these activities. Over time, *Sciences à l'école* has given rise to a national network of activities and programmes, including *Sismo à l'école, Météo à l'école*, and *Genome à l'école* (Eurydice, 2011b:35; Sciences à l'école, 2012). A regional inspector in each *académie* (regional education authority) is in charge of supervising these to ensure their effective implementation.

European Union programmes

The need to boost participation in STEM education and careers is a particular policy focus of the EU (European Communities, 2004; Ruest-Archambault *et al.*, 2008; European Roundtable of Industrialists, 2009). France is involved in their programmes in this area, including one focused on addressing low performance in science. The *Réseau Ambition-Réussite* (Ambition and Success Network) involves primary and lower-secondary schools, and has been targeting participation and performance in science through initiatives like the *J'aime les sciences* (or I like sciences) project at La Rochelle in 2010, and the *Évaluation sur contrat de confiance* (or confidence-based contract) in Besançon between 2006 and 2009. Both programmes aimed to provide personalized support to students encountering difficulties in science and addressing their needs primarily through the restoration of their self-confidence and motivation. A four or five years contract with each participating *académie* (regional education authority) ensures funding and supervision for the Network (Eurydice, 2011b:76). Individual schools take on the responsibility for implementation, the improvement of teaching practices and adoption of any necessary evaluation measures to monitor the programme's effectiveness.

Contests, workshops and other activities

Scientific contests, scientific and technical workshops, and chess have also been promoted in a bid to promote the study of STEM fields. The *Olympiades* are high-level scientific contests intended to enrich the knowledge and culture of participants through national and international competitions. There are several branches of the contest: the Geo-science Olympiad, the Mathematics Olympiad, the Physics Olympiad, the Chemistry Olympiad and the Engineering Olympiad. Participation is open to top performing students, who are chosen by their science teachers and given the responsibility for representing their school. Usually, no more than one child per school is chosen for each category and students compete against others from the same municipality. By contrast, the scientific and technical workshops are open to all students. Participation is voluntary and students are drawn from a number of different secondary schools, regardless of year level. These workshops are, for many students, their first encounter with the world of scientific research and allow students to acquire a thorough understanding of scientific approaches to current societal issues. Because participation is not compulsory, there is some bias in selection of those who can benefit from this opportunity.

Two other initiatives to boost STEM education are directed towards teachers. First, an award for teacher-researchers to recognize professional excellence in the field of science. Awarded by the national Ministry of Education, the *Prime d'Excellence Scientifique*, or Prize of Scientific Excellence, is an incentive for teachers who are also researchers to encourage their children and students to enrol on a scientific research path (Ministère de l'Éducation Nationale, 2012e). The other initiative invites teachers to develop the use of traditional games, including chess, as a means to stimulate their development of cognitive and non-cognitive skills to boost their performance in STEM fields. According to the Ministry of Education, students will develop logic, strategy, rigour, greater concentration skills, autonomous thinking, and intellectual skills favourable to the acquisition of competences in mathematics and science disciplines, such as the ability to think through abstraction (Ministère de l'Éducation Nationale, 2012c).

National scale non-governmental organizations, such as the *Cité de la Science* and the *Palais de la Découverte,* have been established to pursue the Ministry of Education's mission to enhance students' interest in sciences from an early age. In 2010, these two organizations merged, becoming the *Universciences*, a public, industrial and commercial institution whose aim is to make scientific and technical culture accessible to all. The *Universciences* is responsible for elaborating educational programmes, scientific products and activities for primary and secondary school students. Another such organization ambitiously reaching for the same goal is known as *La main à la Pâte*. This is a cooperative scientific organization, created in 2011 by the National Academy of Sciences, and the *École Normale Supérieure* of Paris and Lyon, after the launch of 1992 Physics Nobel Prize winner Georges Charpak's initiative of the same name in 1995 (La Main à la Pâte pour l'Éducation des Sciences, 2012). The Foundation has grown, possessing strong international cooperative links with other scientific research foundations worldwide, and contributing to the improvement of science and technology teaching at the primary and secondary school level. These organisations all take part in the *Fête de la Science*, an annual scientific festival that takes place throughout France in the last week of October. During this festival, there are a series of activities intended to increase children's curiosity and passion for these fields of study.

Programmes targeted at women in science

Another particularly important target for the promotion of STEM fields are women and girls. Throughout recent decades, several national and local initiatives have been directed towards promoting STEM studies and careers to women. The *Pour les sciences* project, launched in 2006 in secondary schools by the municipality of Versailles, was specifically directed at female students and aimed to encourage them to take up scientific careers (Eurydice, 2011b). The exhibition *Les femmes en maths* (Women in Mathematics), organized by the Ministry of Education Research and the Secretariat of Women's Rights, was similarly intended to arouse this ambition through portraits of 16 women who had chosen a successful professional scientific path (Ministère de l'Éducation Nationale et al. No date). Furthermore, the L'Oréal France Foundation undertakes an annual contest for women working in sciences named *Pour les Femmes et Pour la Science* (For women and For Science), electing a few female scientists who they provide grant funding to for specific projects (L'Oréal Foundation France, 2012).

Research

Associations, institutes and university research centres have been working in collaboration with the Ministry of Education to research and develop national initiatives to boost research into the participation in STEM education. A variety of different institutions in France are engaged in research directed at the development and improvement of STEM education and research. A series of pertinent examples from each STEM field is included here.

Firstly, the *Association Nationale pour la Recherche et la Technologie*, the National Association for Research and Technology known as ANRT, and the *Institut National de Recherche en Informatique et en Autonomatique*, known as INRIA are two major national public research organisations dedicated to the study of technology and digital sciences. The focus of ANRT is primarily research, innovation and the development of European partnerships to improve research in the field (Association Nationale pour la Recherche et la Technologie, 2012). In contrast, INRIA is the only public research body fully dedicated to computational sciences from a strong mathematical approach (Institut National de Recherche en Informatique et en Autonomatique, 2012).

Secondly, research in the domain of engineering is led by the *Institut des Sciences de l'Ingénierie et des Systèmes* or Institute for Engineering Sciences and Systems, known as the INSIS, of the National Center for Scientific Research or CNRS. This institute works in cooperation with *L'École des Mines* and *Polytechnique Paris Tech*. These schools are two of the most prestigious French engineering schools. Each has its own research centre through which they participate in the research agenda of INSIS. Their specialty sub-disciplines include Earth and Environmental Sciences, Technology, Nano-technology, Energy, Mechanics and Materials, and Mathematics and Economy (Institut des Sciences de l'Ingénierie et des Systèmes, 2012).

The French Academy of Sciences also supports the development of sciences and research in the field of engineering.

Thirdly, the *École Normale Supérieure's Institut Français de l'Éducation* or French Institute for Education, known as the ENS-INRP, the *École Normale Supérieure Cachan*, and the University of Burgundy's institutes and laboratories all aim to examine policies and produce research pieces that help them advise and work in collaboration with Government on the improvement of STEM education. They play a significant role in the organization of events, such as the 2012 National Mathematics Conference for example (ENS-INRP). Like Australia, France has followed international moves towards greater evaluation of educational outcomes. Accordingly, a significant role is now played by the Evaluation Agency for Research and Higher Education (AERES). Recently established, the AERES responds to the need of the State to measure and evaluate tertiary institutions' performance and managerial efficacy, ostensibly in order to produce a more effective and equitable French education system (Agence d'Évaluation de la Recherche et l'Enseignement Supérieur, 2012). Its focus is limited to higher education.

Finally, the advisory role of the OECD has had an increasing impact in France. The OECD is a leading international organization in policy research, providing many recommendations for its member nations. In May 2011, an OECD/France workshop entitled "Education for Innovation: the Role of Arts and STEM Education" was organized to explore the state of the art and specify lines of investigation for future work regarding STEM education and its impact for innovation (OECD, 2011). More importantly, since the year 2000, the OECD has organized the Global Science Forum, the goal of which is to identify and encourage opportunities for international co-operation in basic scientific research, but also to define international frameworks for vital national or regional science policy decisions (OECD, 2012).

References

Agence d'Évaluation de la Recherche et l'Enseignement Supérieur (2012) AERES, online, *http://www.aeres-evaluation.fr/*, accessed January 2013.

Association Nationale pour la Recherche et la Technologie (2012) *ANRT*, online, *http://www.anrt.asso.fr/*, accessed November 2012.

Campus France (no date) *Les Instituts Universitaires de Technologie en France*, online, *http://ressources.campusfrance.org/catalogues_recherche/diplomes/fr/iut_fr.pdf*, accessed January 2013.

Céreq (2012) *Quand l'École est Finie... Premiers Pas dans la Vie Active d'une Génération, Enquête 2010*. Céreq, France.

Dorier, J-L., Artigue, M., Bolon, J., Charnay, R., Combier, G., Comiti, C., Durand-Guerrier, V., Horvath, G., Paysant, J-J. and Salin, M-H. (No date) *Des mathématiques dans l'éducation française*. Institut de Recherche sur l'Enseignement des Mathématiques (IREM), Paris.

European Communities (2004) *Europe needs more scientists*. Report of the High Level Group on Human Resources for Science and Technology in Europe. Education and Science, Directorate of Science and Society, European Commission, Brussels.

European Communities (2008) *Mapping the maze: Getting more women to the top in research*. Scientific Culture and Gender Issues, Directorate of Science, Economy and Society, European Commission, Brussels. Document Number: EUR 23311 EN.

European Roundtable of Industrialists (2009) *Mathematics, science and technology education report: The case for a European coordinating body.* Report prepared by the ERT Societal Changes Working Group, chaired by Leif Johansson. European Roundtable of Industrialists, Brussels.

Eurostat (2012a) *Female Graduates (ISCED level 5 - 6) in Maths, Science and Technology fields - as % of total female graduates in all fields*, online, http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do, accessed December 2012.

Eurostat (2012b) *Female Students at ISCED level 5 - 6 enroled in the fields of Science, Maths and Computing; Engineering; Manufacturing and Construction,* online, http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do, accessed December 2012.

Eurostat (2012c) *Graduates (ISCED level 5 - 6) in Maths, Science and Technology fields - as % of all fields,* online, http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do, accessed December 2012.

Eurostat (2012d) *Male Graduates (ISCED level 5 - 6) in Maths, Science and Technology fields - as % of total male graduates in all fields,* online, http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do, accessed December 2012.

Eurostat (2012e) *Male Students at ISCED level 5 - 6 enroled in the fields of Science, Maths and Computing; Engineering; Manufacturing and Construction,* online, http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do, accessed December 2012.

Eurostat (2012f) *Students at ISCED level 5 - 6 enroled in the fields of Science, Maths and Computing; Engineering; Manufacturing and Construction,* online, http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do, accessed December 2012.

Eurydice (2011a) *Mathematics Education in Europe: Common Challenges and National Policies*. European Commission, Brussels.

Eurydice (2011b), *Science Education in Europe: National Policies, Practices and Research*. Brussels: European Commission, Brussels.

Fondation Res Publica (2012) *Pourquoi la France manque-t-elle d'ingénieurs et de scientifiques?*, online, *http://www.fondation-res-publica.org/Pourquoi-la-France-manque-t-elle-d-ingenieurs-et-de-scientifiques_a646.html*, accessed January 2013.

Inspection Générale de l'Éducation Nationale (2007) *La Série Scientifique au Cycle Terminal du Lycée: Articulation avec le Cycle de Détermination et Orientation vers les Études Supérieures*. Ministère de l'Éducation Nationale, France. Report Number 2007-090.
Institut des Sciences de l'Ingénierie et des Systèmes (2012) *CNRS*, online, *http://www.cnrs.fr/insis*, accessed November 2012.
Institut National de Recherche en Informatique et en Autonomatique (2012) *INRIA*, online, *http://www.inria.fr/*, accessed November 2012.
L'Oréal Foundation France (2012) *Pour les Femmes et la Science 2012*, online, *http://www.loreal.fr/_fr/_fr/fwis/file/Bourses-LOreal-France-Dossier-de-presse-2012.pdf*, accessed November 2012.
La Main à la Pâte (2012) *Pour l'Éducation des Sciences*, online, *http://www.fondation-lamap.org/*, accessed November 2012.
Ministère de l'Éducation Nationale (2012a) *Mon Nouveau Lycée*, online, *http://www.education.gouv.fr/archives/2011/nouveau-lycee/index.php*, accessed November 2012.
Ministère de l'Éducation Nationale (2012b) *Repères et Références Statistiques sur les Enseignements, la Formation et la Recherche – Édition 2012*. Ministère de l'Éducation Nationale, Paris.
Ministère de l'Éducation Nationale (2012c) *L'enseignement des Sciences de la Maternelle au Baccalauréat*, online, *http://www.education.gouv.fr/cid54197/l-enseignement-des-sciences.html*, accessed November 2012.
Ministère de l'Éducation Nationale (2012d) *Les Grands Principes du Système Éducatif*, online, *http://www.education.gouv.fr/cid162/les-grands-principes.html*, accessed November 2012.
Ministère de l'Éducation Nationale (2012e) *Prime d'Excellence Scientifique 2013*, online, *http://www.enseignementsup-recherche.gouv.fr/cid50548/attribution-de-la-prime-d-excellence-scientifique-en-2013.html*, accessed January 2013.
Ministère de l'Éducation Nationale de l'Enseignement Supérieur et de la Recherche (2011) *Brevet de Technicien Supérieur Environnement Nucléaire.* Ministère de l'Éducation Nationale de la Recherche et de la Technologie, France.
Ministère de l'Éducation Nationale de l'Enseignement Supérieur et de la Recherche (2007), *Brevet de Technicien Supérieur Biotechnologies.* Ministère de l'Éducation Nationale de la Recherche et de la Technologie, France.
Ministère de l'Éducation Nationale de la Recherche et de la Technologie (1998) *Brevet de Technicien Supérieur Génie Optique.* Ministère de l'Éducation Nationale de la Recherche et de la Technologie, France.
Ministère de l'Éducation Nationale de la Recherche et de la Technologie (1997) *Brevet de Technicien Supérieur Chimiste*. Ministère de l'Éducation Nationale de la Recherche et de la Technologie, France.
Ministère de l'Éducation Nationale, Ministère de la Recherche, CNRS and Secretariat for Women's Rights (No date) *Femmes en Maths*, online, *http://www.ihes.fr/~carbone/papers/femmes-en-maths.pdf*, accessed November 2012.
Ministère de l'Enseignement Supérieur et de la Recherche (2012) *Enseignement Supérieur*, online, *http://www.enseignementsup-recherche.gouv.fr/*, accessed November 2012.
OECD (2008) *Encouraging Student Interest in Science and Technology Studies*. OECD Publishing, Paris.
OECD (2011) *Education for Innovation: the Role of Arts and STEM Education*, online, *http://www.oecd.org/edu/ceri/oecdfranceworkshop-educationforinnovationtheroleofartsandstemeducation.htm,* accessed November 2012.
OECD (2012) *The Global Science Forum 2012 Brochure*, online, *http://www.oecd.org/sti/scienceandtechnologypolicy/brochure%20OECD%203_09_2012%20BAT.pdf*, accessed November 2012.
OECD (2012a) *Education at a Glance 2012: OECD Indicators*, OECD Publishing, Paris.

Ruest-Archambault, E., von Tunzelmann, N., Iammarino, S., Jagger, N., Miller, L., Kutlaca, D., Semencenko, S., Popvic-Pantic, S. and Mosurovic, M. (2008) *Benchmarking policy measures for gender equality in science*. Scientific Culture and Gender Issues, Directorate of Science, Economy and Society, European Commission, Brussels. Document Number: EUR 23314.

Sciences à l'école (2012) *Sciences à l'école*, online, *http://www.sciencesalecole.org/,* accessed December 2012.

Stevanovic, B. (2012) "Les filles et les sciences"*,* *Questions Vives*, 6(16):1-15.

World Bank (2012) *World Databank: Percentage of tertiary graduates in engineering, manufacturing and construction*, online, *http://data.worldbank.org/indicator/SE.TER.GRAD.EN.ZS*, accessed January 2013.

World Bank (2012a) *World Databank: Percentage of tertiary graduates in science*, online, *http://data.worldbank.org/indicator/SE.TER.GRAD.SC.ZS*, accessed January 2013.

World Bank (2012b) *World Databank Data Catalog: EdStats UIS.FOSEP.56.F500.F, UIS.FOSEP.56.F400.F, UIS.FOSEP.56.F500, UIS.FOSEP.56.F400*, online, *http://data.worldbank.org/data-catalog*, accessed January 2013.