Consultant Report

Securing Australia's Future

STEM: Country Comparison

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STEM education in Portugal: Education, policies and labor market

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Executive summary

It is suicidal to create a society dependent on science and technology in which hardly anybody knows anything about science and technology, Carl Sagan

For several years, the Portuguese government and education policy leaders have been working on strengthening science, technology, engineering, and mathematics (STEM) education. A large part of this effort was closely related to the fostering of research and development in the country while at the same time increasing the public awareness of science in schools and in the overall population. Concerning STEM, the goals were twofold: 1) to increase the proficiency of all students, as well as teachers in STEM in order to improve the ability of students and teachers to address increasingly complex problems, employ STEM concepts and apply creative and innovative solutions to their daily lives; and 2) increase the number of students who pursue STEM careers and advanced studies by raising awareness of the importance of STEM and by raising interest in STEM subjects. The reasons for this strategy are: STEM skills are understood as critical to foster economic development, while occupations are among the highest paying, fastest growing, and most influential in driving innovation. STEM graduates enjoy low unemployment rates as well.

Portugal is showing rapid progress in improving baseline qualifications, including STEM education, according to OECD reports. However it still lags at upper secondary level (in comparison with other European Union countries), and has one of the lowest attainment rates for secondary education among 25-34 year-olds (52% compared with the OECD average of 82%; Portugal ranks 34 of 36 countries). When it comes to graduation rates, the situation is different. In 2010, the graduation rates exceeded 100% (the OECD average is 84%), and more than 40% of students were older than 25 (OECD, 2012). Moreover, Portugal is producing increasing numbers of STEM graduates: in 2008/09 they made up for 27% of the total number of graduates[1].

The report presents the national strategies set up and implemented in Portugal to foster STEM competencies and qualifications which are the basis for the development of the knowledge-society. It systematically exposes the action plans for the promotion and fostering of STEM in Portugal in primary education, secondary and higher education. The implemented measures aim to have an impact on increasing educational attainment of the Portuguese population and they were created with a goal of raising the general awareness of the value of STEM education. The Portuguese education system has so far implemented a broad national pedagogical reform concerning STEM, via partnerships at local, regional and national level making efficient use of national and European funds. In order to popularize STEM amongst the younger population and foster STEM at all levels of education, Portugal decided to work on two important aspects: the development of effective and attractive STEM curricula and teaching methods, and improved teacher education and professional STEM development. In doing so, Portugal has set up national, regional or local centres to improve the quality of STEM teaching, and in particular, to increase science and technology's popularity and interest, which has also been fostered through specific campaigns and competitions.

The implemented measures addressed the issues of: a) standardization of STEM curricula in primary and upper secondary education (curricular reform, national action plan for mathematics, technological plan); b) supplying qualified STEM educated teachers (technological plan, experimental teaching, *Ciência Viva*); c) preparing pupils and students for post-secondary STEM study (*Ciência Viva*); d) motivating students for STEM (*Ciência Viva*, technological plan, Olympiads, ethnomatematics, mathematical

[1] See http://www.gpeari.mctes.pt/es

plan); e) enhancing the number of graduates in STEM via science and technology policy development (see Section 2); f) improving mathematical and science assessment (technological plan, mathematical plan.); g) preparation for STEM (technological plan-Digital Agenda); h) appropriating labour market needs (see Section 3)

Brief description of the educational system in Portugal

The Portuguese educational system is presented below:

- Pre-school education: It focuses on children aged 3 to 5 years old (until they start the mandatory education). This education takes place in public or private kindergartens, where the former are free of charge (supported by the state). Its attendance is facultative.

- Primary education: It is a component of the mandatory education. It lasts for nine years, organizing itself in three sequential cycles, from 6 years old to 15 year old: 1^{st} cycle refers to the 1^{st} to 4^{th} schooling years (ages 6 to 10 years old); 2^{nd} cycle refers to the 5^{th} and 6^{th} schooling years (10 to 12 years old); and 3^{rd} cycle refers to 7^{th} to 9^{th} year of schooling (12 to 15 years old). The 1^{st} cycle is global and focused on the development of basic competencies in mathematics, Portuguese language, study of the environment, and communication. It works on a full time regime, with 8 hours per day. The schools provide further curricula activities including the mandatory learning of English, study support for all pupils, physical activities, music teaching, and other artistic expressions and foreign languages. The 1^{st} cycle is taught by a single teacher, but specialized teachers can provide support. The 2^{nd} cycle is organized by disciplines and pluridisciplinary study areas. Teaching at the 3^{rd} cycle is organized by disciplines, and the main objectives of this cycle are the development of acquired knowledge, and needed competences to progress to future studies. The 2^{nd} and 3^{rd} cycles are taught by several teachers according to disciplinary speciality. Teaching of ICT is introduced in the 8^{th} year preferably in the project area and is mandatory during the 9^{th} year. During primary education, it is mandatory that students learn at least two foreign languages. At the final of the 3^{rd} cycle pupils have to perform a national exam in the disciplines of mathematics and Portuguese language. Public teaching is free of charge and supported by the state.

- Secondary education: The pupils to accede to this education level need to have completed primary education. From 2011 onwards, this education is mandatory. The curricula has a referential of three years ranging from the 10^{th} to the 12^{th} years (ages 15 to 18 years old) comprehended in four types of courses: 1) scientific-humanistic courses, mainly for those pupils that wish to proceed to higher education, 2) technological courses, for pupils wishing to enter the labor force after concluding secondary education allowing at the same time for them to proceed for higher education studies, 3) artistic courses, for those pupils interested in visual arts, dance and music, allowing a path towards the labor force or a continuation of studies in higher education, and 4) professional courses, focused on entry into the labor market, but allowing also education at post-secondary or higher education. The pupils that complete secondary education are given a diploma of secondary studies, while technological courses, artistic courses and professional courses also confer a diploma of professional qualification.
- Higher Education: It is structured according to the Bologna process principles, and aims at providing a solid scientific, cultural, artistic and technological training allowing for graduates to enter the labor market with strongly developed capacities of conception, creation and critical thinking. Higher education in Portugal is organized as a binary system: a university sector and a polytechnic sector. Both

sectors having public and private higher education institutions. Admission to higher education institutions is dependent on *numerus clausus*. Polytechnic institutes mainly confer technological specialization degrees and bachelors, and some masters. The universities are the only higher education institutions allowed to confer PhDs.

In terms of teachers for maths, physics, chemistry and other STEM fields, not only is there not a shortage of teachers, but Portugal often exports teachers to Portuguese Speaking Language Countries, mainly in Africa and East-Timor.

Fostering STEM in primary and secondary education

An outlook of the mathematics and science curricula

In primary schools, the mathematics curriculum is introduced in a progressive way based on an experimental treatment to form the bases to advance to a more abstract understanding of mathematics. In terms of numbers and operations, the four operations over natural numbers are presented (sum, subtraction, divide, multiply). Operations with negative natural numbers only starts in the 3rd year of basic education, as the pupils gain fluency in calculus and ability to operate these four operations. These operations are gradually extended to the decimal system. As mathematical problems are being solved, each step in the resolution of problems needs to be specified to make sure the pupils completely understand each of the operations. Fractions are geometrically introduced from the decomposition of a linear segment used to express different measurements of size and associated units. The treatment of fractions should be done with the utmost rigor and it is critical that the pupils make sure they interpret correctly the finite decimals as a mere and particular representation of fractions. The study of fractions is a key thematic, and the pupils understanding of them is capital for them to be able to be recognized as having competent knowledge on the thematic. Basic notions of geometry are presented, starting with the visual recognition of objects and elementary concepts as dots, collinearity of dots, directions, and linear segments, parallelism and perpendicularity. From this knowledge, students should build complex objects such as circles, polygons and have a grasp of angles and equality of distances. The equality of angles is presented as well leading to the notion of equality of amplitude.

In the domain of organizing and treating data, emphasis is given to diverse processes and methodologies which allow the interpretation of varied contexts, taking advantage of the conjunct theory. In the third year, the notion of absolute frequency is presented, and in the fourth year, the notion of relative frequency, as well as the representation of rational numbers as percentages. Learning of random processes was left over for more advanced stages of education and not included in the primary education in the discipline of mathematics.

Still in primary schools, technological education is part of the curriculum:

1) recognize the role of technology by identifying the concept of technology and differentiating it from the notion of technical, distinguishing historical contexts of the evolution of technology, identifying the influence of technology in the natural and human environment;
2) discriminate the relevance of the technical object, by defining the concept of technical object, distinguishing the historical evolution of the technical object and impact on society, relating the influence of technical objects as an answer to human needs, interpreting technical objects;
3) acquire technical knowledge, by developing actions oriented towards the decomposition of objects enumerating and analyzing the elements that constitute

them, applying knowledge that evidences objectively the structure of the object, its characteristics and functions;

4) recognize size measurements and instruments of measurement by inferring the existence of diverse type of size measurements (e.g. angle, mass, time, temperature), identifying instruments of measurement (ruler, balance, thermometer);
5) discriminate measurements while executing work, by identifying the importance of precise measurement, establishing the relation between quality of the measurement instrument and prediction of error, articulating with rigor measurement units;
6) know representation as an instrument to register information;
7) apply principles of technologic communication, by identifying vocabulary using it to convey ideas and opinions, interpreting instructions and graphical schematics;
8) develop principles of technological communication, by organizing and illustrate graphical and technical information, producing instructions and graphical schemes using discursive systems, coding and technical symbols;
9) dominate communication as a process to organize facts, by developing actions oriented to be identified in an event chronology, and the development of capacities to enumerate, characterize and register observed facts;
10) distinguish power sources, by identifying natural resources, enumerating and identifying renewable and non-renewable sources of energy, recognizing the environmental impact of power and energy sources;
11) understand processes of production and transformation of energy, by recognizing diverse processes of energy production (e.g. sun, wind, water), analyzing and classifying diverse processes of energy transformation (e.g. electrochemistry);
12) explore energy solutions in the scope of electric operators, by distinguishing electric operators in the construction of simple electric circuits and using electric operators in the development of projects, of low complexity;
13) know analytical procedures of systematization, by developing oriented actions for methodologies to acquire practical knowledge and identify functional units.

In secondary education, the mathematics curriculum encompasses the following subjects: numbers and geometry, including vectors and trigonometry, real functions and infinitesimal analysis, statistics and probabilities. The approach to geometry includes matters associated to synthetic and metrics, analytical geometry, vectorial geometry and trigonometry with numeric calculus competences associated to them. The approach to real functions considers studies from different perspectives including numerical and algebraic graphs, simple functions (algebraic, full, fractionated and transcendent), logarithmic, exponential and trigonometric functions, limit calculus and continuity. The approach to statistics and probabilities complete the basic learning with new notions and tools that could not be taught in primary education. It is encouraged that the teaching of mathematics involves collaboration between teachers of physics and chemistry to help establishing links between common areas of interests between mathematics-physics-chemistry.

Targeted actions to foster interest and learning of STEM related themes:

- The National Action Plan for Mathematics

    - The Mathematics Plan: (Teams for success) is an action plan which fosters systemic development of school projects with the purpose of improving students' knowledge of mathematics (from 5th to 9th grade). "Teams for success" refers to teams of teachers applying for assistance in the development and implementation of innovative three-year projects in the field of mathematics. The assistance is twofold. A mathematics teacher developing an innovative approach to mathematics has to perform it in the classroom. On the other hand, the teachers in the school get support from 80 accompanying expert teachers who work across Portugal with the teachers in the schools.

The Mathematics Plan has been successful, involving 95% of the 2nd and 3rd cycles of all Portuguese compulsory schools by 2011; 462,465 pupils, 18,058 classes and 52,618 teachers. The total investment for such a plan has been around 3 million of Euros per year to support teachers and to buy new equipment (Beernaert, 2008; Beemaert, 2010; Kearney, 2011).

- The new Mathematics programme for basic education originated from the need to adjust the teaching of mathematics for better mathematics learning by pupils. This implies that the mathematics program is organized in cycles and no longer by grade levels. Each cycle has a clearly defined goal, mathematical themes, methodological orientations and all aspects related to curriculum management and assessment. A set of actions has been defined for the purposes of the implementation of the adjusted program and they are as follows: the promotion of professional development programs for teachers teaching at all cycles of basic education (1st to 9th grade); the creation of a database of educational resources for mathematics; the assessment of school mathematics textbooks; the reorganization of teacher education programs.

- The National Action Plan for Science promotes experimental science teaching in the elementary school. It clearly specifies main targets and provisions of the experimental science teaching in elementary schools.

  - The teacher education programme for experimental science teaching in the elementary school started in 2006/07 and aimed at enabling the teachers to use this method with children in the first three years of the compulsory school, so as to improve experimental science teaching (teachers gaining STEM skills themselves) as well as to increase the interest and motivation for science. Experimental science teaching and learning was well-defined and organized accordingly in the following phases: problem identification; classroom discussion with pupils about a problem; drafting the activity plan to tackle the problem; executing plan related activities; collecting data on the activities carried out and drawing conclusions on the problem investigated.

    4-year pilot projects were implemented and executed with the help of teacher educators from 18 institutions of higher education (4 universities and 14 polytechnic institutes). The teacher educators help the science teachers as peers. They are also responsible for organizing final year meetings with all of the science teachers. These meeting have the goal to present the work done in the scope of the program and to stimulate children to orally present their work and activities, making posters and discussing them.

    Teachers who decided to participate in this action were not paid overtime, and all of the extra work they did to carry out the specific tasks as implied by the innovative projects they developed was not paid (it was basically volunteer work). However, their efforts to incorporate experimental teaching were appreciated by the schools and students. Due to the success of the program, it is also going to be applied in kindergartens and in year 4 of the first cycle and years 5 and 6 of the second cycle of compulsory school. Furthermore, the teacher's investment and the commitment to the action will in the near future be an integral part of his or her evaluation. The teacher education programme for experimental science was positively evaluated in 2008, after a three year period.

- Olympiad STEM competitions, encompassing the National Physics Olympiad and National Chemistry Olympiad, are annual competitions for secondary school students, promoted by Physics and Chemistry scientific organizations with the support of the Ministry of Education. The winners of these Olympiads are eligible for full participation in the International Physics Olympiad and International Chemistry Olympiad with national delegations.

  Portuguese secondary school science students who are 16 years of age or younger on December 31st prior to the competition, can also participate in the European Union Science Olympiad (EUSO) since 2009. EUSO is a team competition which tests students' skills and abilities to handle science problems and conduct experiments. It encourages talented science students to develop their full potential and kick-start their careers as scientists. Overall, the competition creates synergies between students and teachers who compare syllabi and educational trends in science education within the EU member states, with the aim of helping to improve science education at the national level.

  The Portuguese Ministry of Education and the Youth Foundation have also signed a protocol which allows students of basic and secondary education to submit research projects in the areas of biology, chemistry, geology, economy, engineering, environmental science, computer science, medical computer science, mathematics and physics and participate in an international conference where the best are chosen to present their work.

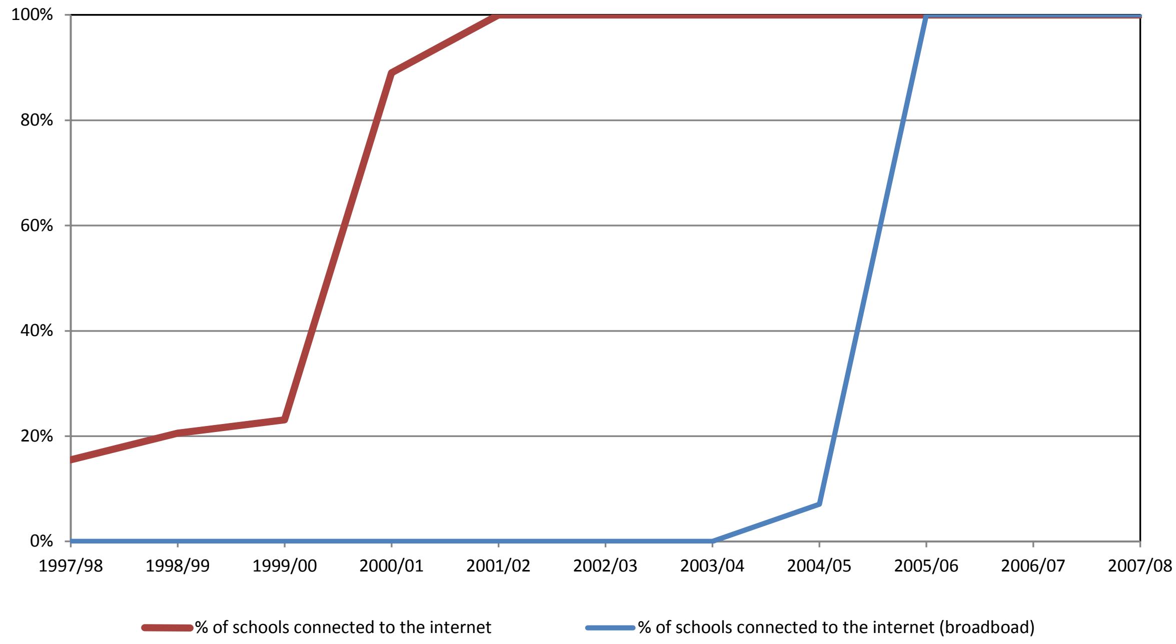
- A curricular plan reform has been performed at secondary level affecting students aged 10-15 years old whereby extra time for science lessons has been granted to schools so that students can be split into two groups, allowing each group the opportunity to work in the laboratory and engage in hands-on activities.

  Within the scope of curricular reforms, the Portuguese Ministry for Education has issued specific guidelines for using ICT throughout the school curriculum for STEM teaching and learning for each subject (for example, in Portugal the methodological recommendations for the Mathematics syllabus suggest the use of graphic calculators, and geometry software such as Geogebra). General learning outcomes in the area of ICT are also specified, and are based on a trans-disciplinary principle.

- The Technological Plan was approved in 2005 by the Portuguese Council of Ministers. This was an ambitious plan to upgrade the economic and scientific system in Portugal by stimulating science based activities. The plan was transversal to several educational, economic and social systems. In terms of its impact on primary and secondary schools, it aimed at enhancing knowledge, production and innovation, as well as scientific and technological competences. Several actions were performed in order to assure that the aims of the plan have been fulfilled:

  - High-speed broadband internet access among schools (Figure 1);
  - Internet access in all classrooms and all school spaces (Figure 1);
  - Programme e.escola 2.0. This programme was designed to meet the Digital Agenda objectives, and to guarantee the continuity of access to laptops and internet connection, with special conditions for the educative community; to promote the creation and use of digital content; and, to foster the use of next-generation networks;

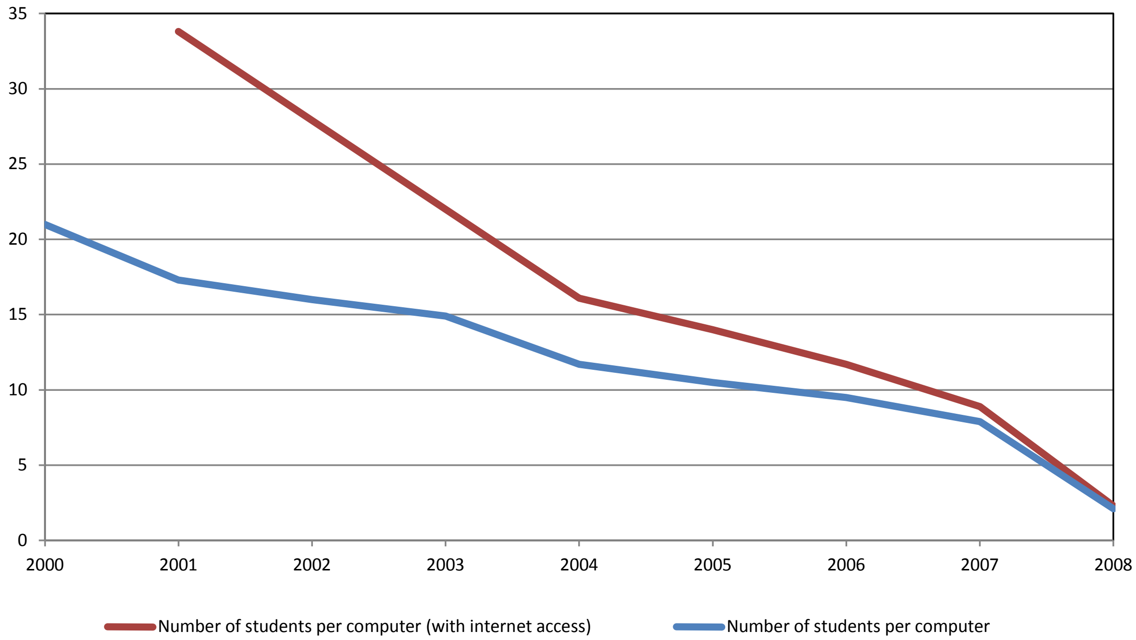
Figure 1 – Schools connected to the internet by the Science, Technology and Society network



Note: % of schools connected to the internet mean that these schools are connected to the internet by any means (e.g. dial-up); the figure shows that only from 2003/2004 onwards the connections started to be implemented using broadband connectivity.
Source: GEPE - Gabinete de Estatística e Planeamento da Educação, FCCN - Fundação para a Computação Científica Nacional.

- Technological kits: This was a measure to increase IT equipment in the classroom so as to promote the interactivity and innovation of the pedagogical practices;
- The school portal: The school portal served as a reference site for schools in Portugal for sharing digital learning resources, e-learning, communication, collaborative work and access to support services for school administration;
- Simplex school: An information system based on an electronic platform and on a service-oriented infrastructure allowing for a simplification of the school management. Its goals are to provide schools and the Ministry of Education organisms with quality web services streamlining management processes that are critical to the educational system, and ensure that the construction of the information system respects the principles of economy and efficiency in the acquisition of IT and financing services;
- Stimulating ICT competencies training and certification: The Technological plan enabled flexible, segmented and disciplinary oriented training and certification of ICT skills;
- *Escola virtual* (Virtual School): Virtual School is an e-learning platform owned by the publishing group *Porto Editora*, a Portuguese private company. Access to the program may be granted on an individual or institutional basis. The program allows for the transformation of subjects from 1st to 12th school year into interactive lessons where text, animations, videos, phrases and exercises are combined and make learning simple and effective;
- *E-escolinha*: A project which enabled access to a laptop with learning resources to students of first cycle schools (Figure 2);

Figure 2 – Number of students per computer in primary and secondary education (total and with connection to the internet), 2000-2008



Source: GEPE - Gabinete de Estatística e Planeamento da Educação.

- *Escola móvel* project (Mobile School): This project is a distance learning project, using a technology platform (LMS Moodle) to support learning for students of the 3rd cycle of basic education, children of people who frequently change their place of residency, children and youth from poor communities, those at risk of dropping out, as well as for children supported by the institution *Ajuda de Mãe* (Mother's Help) who have not completed their education in time. The curriculum of the Mobile School was initially constituted by the disciplines that make up the National Curriculum for Basic Education 3rd Cycle, with the exception of Physical Education. The work aimed to provide differentiated learning contexts and individualized tutoring.

  Within the scope of the Technological Plan, two other projects were created with the aim to promote partnerships between educational institutions and enterprises, namely:

  - ICT internships – workplace training for vocational education students at top national and international technological companies;
  - ICT academies – creation of ICT academies from technological companies in schools, aiming to reinforce student's qualifications and their entry in the job market.

- The *Champimóvel* Project: a joint cooperative between the *Champalimaud* Foundation and the Portuguese Ministry of Education and Science which provides an experience of the human body, dealing with the most relevant and contemporary issues in medical science such as stem cells, nanotechnology, DNA and gene therapy. This is done by using the Champimóvel, a 3-dimensional, interactive and transportable simulator. It was introduced as a part of the STEM objectives in the educational curriculum in 2008 to Portuguese youngsters aged between 9 and 14 years old. This educational programme is a unique learning experience, motivating and sustaining young peoples' curiosity in science, and particularly biomedical science careers.

- *Ciência Viva*: Promotion of scientific culture in schools and with the general public National Agency for Scientific and Technological Culture*, Ciência Viva*, was set up in 1996 to promote public awareness of science and technology. Since then, it has successfully organized: work experience placements for secondary students in science laboratories, a Science and Technology Week, debates with scientists and other awareness raising events and activities for the general public, such as summer courses ''Astronomy in the Summer'', ''Geology in the Summer'' and ''Biology in the Summer''. Apart from its basic activities it has a special school programme to support and stimulate the use of experimental teaching methods including the hands-on teaching of science, and to help schools with practical activities involved in their science and technology projects. Examples of actions implemented under the scope of the *Ciencia Viva* program are described below:

    - Summer placements for 15 to 18 years old students are opportunities to work in a real research laboratory in cooperation with researchers (usually based at university research centres) for two weeks. The objective is to stimulate interest in research and research professions. Examples of summer placement projects:
        - Open Lab: involving secondary students in research and making experiments supervised by a researcher during two weeks; at the end they make a written and oral presentation.
        - Auto lab: research on a project which consists of a car with pedagogical boxes that goes to the schools;
        - Cancer mobile: research on a project raising awareness on the methods of cancer prevention;
        - Science lab: a project on which young people do research and carry out experiments in cooperation with the Museum of Transport and Communication.

      IPATIMUP has also organized several activities that promoted life sciences in the north of Portugal and which were developed in cooperation with several local organizations: experiments with primary school pupils in *Porto*, training sessions for primary school teachers, inviting friends of primary school pupils to participate in one of their science activities, cooperating with the town of *Trofa* to promote science education, organizing science activities for families and the general public during holidays in the summer, conducting lectures at schools "Science on Mondays" which implies a visit to IPATIMUP.

    - Science in the summer consists of organized science activities all across Portugal and involves cooperation with NGOs, local authorities, and higher education institutions among others. These initiatives encompass a wide variety of science fields, such as astronomy, geology, biology, and engineering. They include field trips, field work, observations, laboratories on the beach, keynote lectures for the public, and visits to lighthouses.

    - The Robotics Open Festival is an initiative which involves several activities and competitions with robotics (Robocop Dance competition, cooperation with companies on projects) according to the age of the pupils involved. One of the most interesting contributions of this initiative is The Portuguese Robotics Open Festival, which had its 1st edition in 2001, and which aims at promoting science and technology among students from the 1st grade to university studies, as well among the general public, through robot competitions. The Festival takes place every year in a different city, and includes also an international conference where national and international researchers present their latest work in the field of Robotics.

- MIT professors go to school is an activity based on an official partnership of Portugal with MIT for research. Professors go to schools to inform and debate with students on mathematics and science topics.

- The ORION Amateur scientific association is responsible for setting up different activities concerning astronomy for pupils in schools or the public at large. The members who are responsible for the implementation of the activities are teachers investing their free time in the promotion of science. The association also produces its own pedagogical material based in the field of astronomy, physics and other STEM related fields.

- Debates with scientists and researchers on topics such as Nanotechnology are also one of the examples of the implementation of the *Ciência Viva*, where youngsters have the opportunity to contact directly young scientists and researchers working on issues related to the various STEM fields, particularly under a trans-disciplinary approach.

- *Census Viva* is a new didactics approach to teaching statistics in schools. The project is based on using a methodology of analysing data which consists of using real data concerning the population and other statistically measurable issues in Portugal. The objectives of this project, supported by the University of Minho, are to increase the students' interest in mathematics by using real life data, especially from the environment in which they live and to attract more students to mathematics education in higher education studies.

- The LONGEVA project is a science project for 7^{th} and 8^{th} graders (12 to 15 years of age) on aspects and different ways of life enhancement and longevity through sciences such as chemistry and biology. Pupils comment on the use of substances that can make life longer and they also do experiments to test their hypotheses. The results of the projects, drafted by the pupils are published in the proceedings of scientific congress for youngsters in the USA. The project is implemented during extracurricular activities at school.

- Ethnomathematics is a project supported by the University of *Trás-os-Montes and Alto Douro* (UTAD) which aims at focusing on cultural heritage to promote education and in particular increase motivation in learning mathematics. The plan for using cultural heritage in teaching and learning mathematics is first conceived in combined efforts by university professors and teachers in schools. The execution of the proposed plan takes place in the form of fieldtrips, work in the classroom and experiments. This science projects focuses on the study of the mathematical ideas and practices that are imbedded in professional groups, on daily mathematical practices and patterns of organizing daily life in contemporary societies. Ethno mathematics thus enables to connect with the children's reality and bring the surrounding world of the child in the classroom.

- The FORUM *Ciência Viva* is an activity which gathers the representatives of a large selection of projects funded within the framework of the call for projects.

- The *Association Ludus* (within the scope of *Ciência Viva*) is a non-profit organization promoting recreational mathematics in particular through the use of mathematics games. *Ludus* is responsible for organizing the national championship of mathematics games, but also meetings, seminars, workshops and study visits and congresses on how to use mathematics games to raise interest in mathematics. It also organizes exchanges with national and international organizations which share the same objective. Moreover, the association publishes books and manuals on recreational mathematics and mathematics games.

- *Ciência Viva Centres* comprises 17 interactive science centres with the aim of promoting scientific culture and raising awareness as well as interest in science of the general public. The centres are conceived as interactive spaces fostering scientific, cultural, and economic regional development. In-service training courses are organized to show teachers how they can use the centres to support their science and technology teaching in schools.

Fostering STEM in higher education

The Portuguese higher education system has been changing at an accelerated rate in the last decade. Recently, it has been reformed, and the development of science policies associated with a strong public investment led to an unprecedented number of new graduates and specifically doctorates being awarded in all disciplinary fields by Portuguese universities (more than 1500 doctorates per year since 2008, around half of them from STEM fields). Moreover, there have been policies fostering science and technology as well as research and development at universities. Collaborations between research centers and companies as well as internationalization and networking have become increasingly important and the creation of a strong scientific base has been one of the basic guidelines in the development of higher education in Portugal (Horta, 2010).

Development of STEM in higher education in Portugal has been directly addressed by the government in recent years, and fostered by the implementation of national science policy and strategies for higher education. Historical statistical data on the trends in student numbers in STEM shows that there has been an increase in the number of STEM enrolments and graduates. The number of students enrolled in STEM courses in the Portuguese higher education has been increasing since 1995. In 2008/09, the percentage of those enrolled in STEM courses (both STEM1 AND STEM2) was around 31% of the total number enrolled in higher education which was 373,002[2].

STEM1 courses are related to the typical bachelor courses in STEM areas (e.g. mathematics, physics, engineering) while the STEM2 courses refer to vocational short term cycles (Technological Specialization Courses or CETs) which rose more than 20-fold relative to 2005, with polytechnics accounting for about 80% of them. Nevertheless, these short-term cycles still account for only 3.5% of all polytechnic students (although it was below 0.05% in 2005) and there is therefore still a large potential for growth in polytechnics of short-term professional and vocational training. The Technological Specialization Courses were regulated (Decree-Law 88/2006) to increase the availability of technical and vocational education and widen access, based on studies that demonstrated that technological and vocational courses diminish retention, dropouts, and are essential to economic growth (see OECD, 2010).

Table 1: Number of students enrolled to STEM courses in higher education in Portugal, 1995/06 to 2008/09

	95/96	*96/97*	*97/98*	*98/99*	*99/00*	*00/01*	*01/02*	*02/03*	*03/04*	*04/05*	*05/06*	*06/07*	*07/08*	*08/09*
HE STEM1 Courses-	*87 659*	*94 355*	*100 747*	*105 292*	*108 247*	*111 646*	*114 251*	*116 733*	*116 435*	*112 107*	*107 433*	*108 521*	*112 389*	*110 056*
Technological Specialized Courses-CET STEM2	-	-	-	-	-	-	-	-	-	*134*	*689*	*1 144*	*2 569*	*2 963*

Source: http://www.gpeari.mctes.pt/es

[2] See http://www.gpeari.mctes.pt/es

The number of graduates from STEM courses (STEM1 and STEM2) has also been growing in Portugal since 1995. The growth rate increased significantly in 2006/07 when the number of graduates was 50% higher than the previous year (from 14,613 in 2005/06 to 23,413 in 2006/07)[3].

Table 2: Number of graduated from STEM courses in Portugal (1995/06 to 2008/09)

	95/06	*96/97*	*97/98*	*98/99*	*99/00*	*00/01*	*01/02*	*02/03*	*03/04*	*04/05*	*05/06*	*06*
HE -STEM1	*7232*	*8 219*	*9 293*	*9 809*	*10 199*	*10 567*	*12 107*	*13 145*	*14 016*	*14 715*	*14 503*	*20*
Technological Specialized Courses-CET STEM2	-	-	-	-	-	-	-	-	-	-	*110*	*4*

Source: http://www.gpeari.mctes.pt/es

In 2005, more than 4 million tertiary students in the EU-27 were specialising in either 'science, mathematics and computing' or 'engineering, manufacturing and construction'. Although science degrees attracted more than 1.7 million students in 2005, this subject was less popular than engineering studies (Eurostat, 2009). STEM courses have also become a popular choice of study for many Portuguese students in recent years. The current percentage of secondary students who wish to undertake an engineering program in Portugal is 23%[4], and the percentage of all students who plan a career in engineering and computing in Portugal is 15% in total (Australia around 9%), according to PISA 2006 (OECD, 2012-*PISA 2006 Database)*, which is above the OECD average. Female students tend to be less likely to undertake a STEM program according to the Eurostat data from 2009, which measured graduates in science and technology per 1000 of population aged 20-29 years (Eurostat, 2009). Portugal's share of female participation in STEM studies is around 15% and male 26% whereas within the EU, Denmark and Bulgaria ranked highest in terms of female participation in STEM studies, with 33.1% and 32.0% respectively.

Gender breakdown of entrance into higher education in Portugal (a focus on a STEM field: engineering): biomedical engineering cc. 40% male, 60% female; civil engineering cc. 70-75% male and 25% female; chemical engineering cc. 40% male and 60% female; electrical/computing cc. 90% male and 10% female; mechanical/industrial processing cc. 90% male and 10% female[5]. Engineering programs are believed to be important or very important (25% and 74% respectively)[6] in Portugal. Also some of the most common traits and characteristics associated with engineers generate a quite positive image of engineers among the general population. Engineers are seen as dynamic, creative, affirmative, active and entrepreneurs. This image has persisted throughout the years and has been also fostered via science and technology reforms of higher education implemented in recent years by the Portuguese government. These reforms have fostered STEM in higher education, and have contributed to the popularization of enrollment in STEM courses.

This report will give a brief overview of these reforms and their impact on the promotion of undertaking STEM courses in Portugal:

- The National Agency for Scientific and Technological Culture, "*Ciência Viva"*, promotes science and technology culture and education and fosters science awareness, science education and the role of science in the daily life of citizens. It

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3 See http://www.gpeari.mctes.pt/es

4 Data obtained via *Attract* project, which sampled and analyzed secondary and entrant students' perceptions of the engineering profession in several member countries.

5 http://www.attractproject.org/

6 http://www.attractproject.org/

does so via several activities and projects already mentioned in Section 1 of this report. Ciência Viva activities have been aiming at teachers and students at primary and secondary levels as well as the general public. However they were implemented by university professors and organized by academics and researchers from universities and research centres from around the country. Among those activities, the most related to promoting STEM courses in higher education are the following:

- the creation of an integrated network of 18 science centres throughout the country (as launched in 1999, and extended initially to 10 centres in 2005), and 3 additional science centres (MCTES, 2010);
- organization of the "science in the summer" programs and spending time at research centres such as IPATIMUP, which has involved last year more than 17,000 people and over 140 research institutions;
- raising scientific awareness via science projects at schools, which involved more than 1,000 projects throughout the country in the past two years;
- organizing science internships for secondary school students, involving more than 7,000 youngsters (15 to 18 years old) over the last decade (MCTES, 2010).

- Scientific employment: In recent years, the Portuguese Ministry of Education of Science has been implementing policies to boost the number of PhD holders in the country and has promoted scientific employment through a new program launched in 2007 to support contractual arrangements for researchers. Nearly 1200 new PhD researchers were hired by the summer 2009 (of which 41% were foreigners), based at 264 R&D different institutions (mostly in the scientific areas of natural and exact sciences, 43%, and engineering and technology, 24%).

- Technology-based start-ups: In recent years, a significant increase in the proportion of knowledge based firms in Portugal can be observed. According to the indicators of economic activity it grew from 6.4% in 1991 to 9.8% in 2003, corresponding to a 3% growth in the number of firms involved in knowledge related activities. The firms responsible for this type of growth are mainly offering business services; of which 10% are firms providing high-tech services (including communications and computer activities) and these represent a share of 70% of all new firms in high-tech sectors. Other new start-ups have also derived from an increased innovative activity in the medical sector, responsible for 6% of all new firms in the period 2002-2007, followed by the pharmaceutical (2.5%), the industrial equipment (2%), and the fabrication of electronic components (1.5%). These firms represent high-growth activities, also with higher survival rates.

  New high tech firms are usually started by STEM graduates, as 27% of the entrepreneurs are graduated in engineering, 18% in medical sciences, whereas only 9% of the entrepreneurs are graduated in administration and commercial trade, and 9% in humanities.

- Fostering research networks, through international partnerships: In 2006, a strategic program of international partnerships in science, technology and higher education was initiated with the aim of bringing together several Portuguese universities and leading universities worldwide, including MIT, Carnegie Mellon University and the University of Texas at Austin. These partnerships have been extremely successful in fostering STEM networks in research and teaching in Portugal, and also in promoting industry-science relations[7]. An important new element driving institutional building in the Portuguese research landscape, together with accelerating university

[7] http://alfa.fct.mctes.pt/apoios/cooptrans/parcerias/index.phtml.pt

reform, has been strategically-oriented international partnerships, bringing together universities, research centres, end users, and innovative businesses.

These partnerships have aimed at fostering high-quality research platforms associated with the design, testing and implementation of new products and systems for markets worldwide, as well as at training future leaders in cutting-edge areas of science and technology. They have created some fully-integrated “test beds” in Portugal, as scalable “living laboratories” to test emerging technologies and systems in a way to facilitate the access of businesses and industry to leading markets worldwide.

They have brought together several Portuguese universities and other world-ranking universities, including MIT, Carnegie Mellon University, Harvard Medical School and the University of Texas at Austin. These initiatives, unprecedented in Portugal and with innovative features worldwide, have opened the way for setting up a number of thematic networks with industry and across various Portuguese universities.
By September 2007, the first national doctoral and advanced studies programmes within these partnerships were operational (in some cases offering dual degrees between US and Portuguese universities). These international partnerships involved funding of over 177 million euros for the first five years, and brought together a large number of Portuguese research institutions and private sector companies through collaborative advanced research projects and sustainable efforts to stimulate new knowledge and exploit new ideas for markets worldwide.

The networks brought together a large number of Portuguese institutions with the purpose of pushing forward their international outreach through advanced studies projects and through ongoing ventures for generating new knowledge and exploiting new ideas in conjunction with firms and institutions of high international repute and standing.

The partnerships themselves:

- The MIT-Portugal Program was launched in October 2006 in the fields of transportation systems, sustainable energy, stem cell engineering for innovative therapies in regenerative medicine, and materials and design-inspired products with specific applications in electric mobility and new medical devices. The program was oriented towards fostering STEM graduates as it offered mostly “engineering” related courses. Overall, the program had involved over 340 master and doctorate students at the beginning of its 3rd year in September 2009.

- The Carnegie Mellon Portugal Program was launched in October 2006 with dual professional masters and PhD programs offered in the fields of information and communication technologies. It covered areas such as new generation networks, software engineering, cyber-physical systems for ambient intelligence, human-centric computing (including language technology), public policy and entrepreneurship research, and applied mathematics.

- University of Texas in Austin-Portugal program. The programme was responsible for launching a “Collaboratory for Emerging Technologies, CoLab” in March 2007, which focused on collaborative research in advanced interactive digital media and integrating advanced computing and applied mathematics.

- The Harvard Medical School-Portugal Program was launched in May 2009 to foster translational and clinical research programs and the development of a new infrastructure for delivering medical information produced by medical schools to medical students across the academic institutions, to health practitioners and to the general public, thus contributing to strengthening the relationships of medical schools and health science institutions with their main constituencies.

- International Iberian Nanotechnology Laboratory (INL): The international Iberian Nanotechnology Laboratory is the first, and so far the only, fully international research organization in Europe dedicated to nanoscience and nanotechnology. It is the result of a joint decision of the Portuguese and Spanish governments, taken on 19 November 2005 at the XXI Portugal-Spain Summit in Évora, whereby the two Governments made clear their commitment to close cooperation in ambitious science and technology joint ventures for the future. The new laboratory is being established by Portugal and Spain, but in the future membership will be open to other countries in Europe and other regions of the world.

    - INL has an international legal framework similar to that of the few international laboratories in other areas located in Europe (e.g., CERN – European Organization for Nuclear Research at Geneva, ESO – European Southern Observatory, EMBL – European Molecular Biology Laboratory, and ESRF – European Synchrotron Radiation Facility).
    - INL was installed in Braga, Portugal, on a 47,000-m^2 site, close to the Gualtar campus of Minho University, with the Spanish professor José Rivas as its first director. It is planned to recruit 200 researchers from all over the world, aiming at international excellence.
    - INL was officially launched on 18 January 2008, at the XXIII Portugal-Spain Summit in Braga, with a symbolic “foundation stone” formed 500 million years ago when the Iberian Peninsula was taking shape and a nano-inscription.
    - INL was officially inaugurated on 17 July 2009, with a built area of about 20,000 m^2, comprising advanced specialist facilities and several laboratories with state-of-the-art equipment, among them a class-100 central micro- and nanofabrication clean room of about 700 m^2.
    - By the end of 2009 several new international partnerships had been signed with leading scientific institutions worldwide, including MIT and the Max Planck Society, which are facilitating joint recruitment of senior and junior researchers, as well as the development of an internationally recognized research agenda. The choice of priority research areas was based on the strategic areas recommended by INL’s Management Board, in existing current areas of excellence in nanoscience and nanotechnology in Portugal and Spain and on economic needs and opportunities identified in both countries. Based on these criteria four priority research areas were selected: nanomedicine; environmental monitoring, safety, and food quality control; nanoelectronics (beyond CMOS); and nanomachines and nanomanipulation.

- First Fraunhofer Institute in Europe outside Germany: The Institute was established out of the need for the development and research on emerging information and communication technologies, such as “Ambient Assisted Living”. The Institute will be responsible for co-operative projects involving several Portuguese institutions and Fraunhofer institutes in Germany.

- *Champalimaud Centre for the Unknown*: The Champalimaud Foundation was created in 2004 by the bequest left by the Portuguese industrialist and entrepreneur, the late António Champalimaud. It focuses on biomedical science and seeks to extend research in the fields of oncology and neuroscience, as well as to advance the field of ophthalmology.

- On 5 October 2010, the Champalimaud Foundation inaugurated a state-of-the-art research facility, the *Champalimaud Centre for the Unknown*, to contribute to its objective of developing biomedical research in Portugal. It will be a multidisciplinary centre for translational research of excellence, with the best possible conditions to attract and retain the best researchers, academics and medical doctors from Portugal and abroad in the fields of neuroscience and oncology.
- Through a detailed programme of research and clinical support, the Foundation strives to make significant scientific progress, particularly in the fields of cancer research and neuroscience.

Labour market for STEM graduates

Popularization of higher education STEM courses attendance as well as a higher percentage of STEM graduates is not just a result of national/local policy actions, or science and technology policies implemented over the years. It is also related to a perception that STEM graduation offers better guarantees of employment. In a country like Portugal, which is facing severe financial austerity measures, and a stagnant economy, securing a job after graduation has become increasingly important for future students' decisions upon choosing a higher education course. These arguments are supported by statistical information concerning 2011.

The percentage of those unemployed with a higher education degree as compared to the total number of unemployment in Portugal is 8.6%[8]. When it comes to STEM degrees, it may be observed that those who have graduated from mathematics, statistics or informatics have a lower percentage of unemployment (0.6%, 8.3% and 1.2% respectively) when compared to those with higher education degrees in other fields, such as the humanities or social sciences (5.2% and 12%-Table 3).

Table 3: Unemployed with a higher education degree in Portugal in June 2011

Area of study	**Total**			
	Male		**Female**	
	N.º	%	N.º	%
14 - Educational Sciences	468	12.1%	3 406	87.9%
21 – Arts	921	35.2%	1 696	64.8%
22 – Humanities	513	23.2%	1 700	76.8%
31 – Social Sciences and Behavioural Sciences	1 428	27.9%	3 696	72.1%
32 – Journalism	420	27.1%	1 132	72.9%
34 – Business Sciences	2 834	35.3%	5 205	64.7%
38 – Law	432	29.4%	1 036	70.6%
42 – Life Sciences	171	25.8%	493	74.2%
44 – Physics	231	35.5%	419	64.5%
46 – Mathematics and Statistics	71	30.0%	166	70.0%
48 – Informatics	325	64.2%	181	35.8%
52 – Engineering and Technical Sciences	2 488	70.4%	1 047	29.6%
54 – Manufacturing	223	28.1%	572	71.9%
58 – Architecture and Civil Engineering	1 888	57.8%	1 380	42.2%
62 – Agriculture and Fisheries	402	43.2%	528	56.8%
64 – Veterinary Sciences	56	29.2%	136	70.8%
72 – Health	528	19.2%	2 224	80.8%
76 – Social Services	125	6.4%	1 829	93.6%
81 – Administration	560	36.0%	996	64.0%
84 – Transport	30	88.2%	4	11.8%

[8] http://www.gpeari.mctes.pt/es

85 – Environmental Protection	207	31.0%	461	69.0%
86 – Security	45	47.4%	50	52.6%
Subtotal	14 366	33.6%	28 357	66.4%
No area	18	52.9%	16	47.1%
TOTAL	**14 384**	**33.6%**	**28 373**	**66.4%**

Source: http://www.gpeari.mctes.pt/es

Concerning gender, there seems to be no difference in terms of the number of the unemployed, however there is a difference in terms of gender of those with a higher education degree which are unemployed (Table 4). Female unemployment is twice as high as males'.

Table 4: Unemployed by gender in June 2011

Gender	**Total number of unemployed**		**Unemployed with higher education degree**	
	N.º	%	N.º	%
Male	229 283	46.4%	14 384	33.6%
Female	265 043	53.6%	28 373	66.4%
TOTAL	**494 326**	**100.0%**	**42 757**	**100.0%**

Source: http://www.gpeari.mctes.pt/es

Male unemployment in engineering and informatics is higher than females' (70.4% and 64.2% respectively). Female unemployment is much higher in the areas of mathematics, statistics and sciences (70% for mathematics and statistics, 74.2% for life sciences and 64.5% for physics; see Table 5) when compared to male unemployment in the same areas.

Table 5: Unemployed by gender and area of study (higher education degree) in June 2011

Area of study	**Total**	
	N.º	% Subtotal
14 – Educational Sciences	3 874	9.1%
21 – Arts	2 617	6.1%
22 – Humanities	2 213	5.2%
31 – Social Sciences and Behavioural Sciences	5 124	12.0%
32 – Journalism	1 552	3.6%
34 – Business Sciences	8 039	18.8%
38 – Law	1 468	3.4%
42 – Life Sciences	664	1.6%
44 – Physics	650	1.5%
46 – Statistics and Mathematics	237	0.6%
48 – Informatics	506	1.2%
52 – Engineering and Technical Sciences	3 535	8.3%
54 – Manufacturing	795	1.9%
58 – Architecture and Civil Engineering	3 268	7.6%
62 – Agriculture and Fisheries	930	2.2%
64 – Veterinary Sciences	192	0.4%
72 – Health	2 752	6.4%
76 – Social Services	1 954	4.6%
81 – Administration	1 556	3.6%
84 – Transport	34	0.1%
85 – Environmental Protection	668	1.6%
86 – Security	95	0.2%
Subtotal	42 723	100.0%
No area	34	
TOTAL	**42 757**	

Source: http://www.gpeari.mctes.pt/es

Career prospects

Based on the statistical analysis it appears that those who have graduated from STEM degrees have higher chances of employment that those who have gotten their higher education degree in other fields. Also, when analysing the current job offers on the market, more than 50% of the job offers usually tend to ask specifically for a STEM professional and about 20% offers ask for an engineer[9]. The general job offers did not specify specific skills needed for a STEM graduate to apply. The rest of the offers request specific education areas such as health, business or management.

Table 6: Job Offers poster between the 7th and 14th of September 2010 at a Portuguese journal

Type of offer	%
Only for Engineers	20
General request	51
Not for engineers	29

Source: Attract project

The majority of the job offers for STEM professionals required some sort of professional experience and the possession of core STEM skills. Aside from the STEM skills, some of the most mentioned were: planning and organization, leadership, good command of the English language and goal orientation. On the basis of statistical data and general opinion on STEM degrees in Portugal, one concludes that STEM courses are mentioned in a positive way in relation to the labour market since they have long been put in relation to a good employment outlook and a high salary.

9 http://www.attractproject.org/

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