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NUCLEAR ENGINEERING EDUCATION IN ITALIAN UNIVERSITIES

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ABSTRACT

The paper illustrates the evolution and the present situation of the university-level nuclear engineering education in Italy. The problems connected with the need of qualified faculty in view of a dramatic increase of students is pointed out. A short description of the programs at present available at Italian universities is also presented, together with some statistics referred to Politecnico di Torino. The mathematical and computation content of each programs is also analyzed.

Key Words: Nuclear education, Nuclear engineering, Human resources.

1. INTRODUCTION

It is a widely shared opinion that nuclear education is playing a fundamental role to enhance the current and future nuclear renaissance. Unfortunately, in the last two decades in almost all countries, universities have experienced quite severe reductions in the nuclear engineering programs at all levels, due to the decline of the number of students and to the generalized cut of funding. In the Italian situation the problem has become really dramatic, because the country has pulled out of the nuclear generation of electricity and resources have been practically cancelled for the universities where nuclear programs were active.

Education of qualified nuclear specialists has now become a big concern of international organizations and, more recently, of nuclear industry and research laboratories. The problem may be serious even for the maintaining of the existing nuclear panorama and without looking forward to a tumultuous nuclear renaissance. Particularly significant is a recent statement by OECD [1], where the availability of qualified human resources is deemed to be a prerequisite to the safe operation of existing nuclear power plants as well as to the recourse to nuclear energy in general. Hence the OECD Steering Committee for Nuclear Energy is conveying to the member governments a warning to suggest a regular monitoring of the availability and requirements of qualified human resources to match the existing and future needs. It is particularly stressed that "governments, academia, industry and research organizations should collaborate, both nationally and internationally, to enhance nuclear education and availability of nuclear expertise, including financial support to universities and scholarships to students". Something that in Italy universities have not experienced at all. Furthermore, "governments, whether or not they choose to utilize nuclear power, should also encourage large, high-profile, international R&D programs

which attract students and young professionals to become the nuclear experts required for the future". Something that short-view planners have not done at all, all over the world.

Talking to deaf, the agency has strongly stimulated the governments to consider the issue as strategic and act as soon as possible in order to revitalize nuclear education with a strong commitment to vigorously support research to maintain high quality training. Similar concerns for nuclear education have been also stated by the European Nuclear Society in very recent times [2].

2. THE ITALIAN SITUATION

As pointed out above, in Europe, but especially in Italy, universities have gone through two decades of hard time as far as financial and human resources are concerned. The Italian situation is worse in the nuclear field as compared to other countries, because of the even larger reduction experienced with respect to other disciplines because of the specific national situation. Of particular concern is the state of the faculty operating in nuclear engineering programs. Very few young people have been hired in the last twenty years, leading to an age spectrum naturally and dangerously biased towards what can be euphemistically called "mature age". In a few years retirement of several professors will practically empty many nuclear groups in some Italian universities, making very hard indeed to maintain nuclear engineering programs.

The slimming of nuclear groups has also another important consequence: participation to important research projects is becoming difficult, with a chain effect leading to a further reduction of financial resources for doctorate programs and to a de-qualification of the education. It should also be stressed that the operation leading to re-establish a satisfactory numerical level of the nuclear engineering faculty cannot be carried out as a Heaviside function process. Good students should first be attracted to the field, trained with high-level courses, motivated towards a doctorate, given opportunities for post-docs and then again motivated to an academic career with clear opportunities. The whole process may require at least ten years and thus even a decision taken today may not yield benefits in time for the foreseen nuclear industrial development.

Even in such a difficult situation, the Italian nuclear engineering education system has done its best to maintain the excellence of programs and to enter international cooperation frameworks. It has been still possible to attract good and motivated students. The collaboration among universities offering nuclear programs has been enhanced both at the Italian and at the international level. The institution of an Italian consortium of universities (CIRTEN) has allowed to keep alive both scientific research and education at a satisfactory rank. At the European level, a large-scale consortium of universities (ENEN), that includes CIRTEN, has been set up for establishing common requirements for a mutual recognition of degrees. The objectives of the European Master of Science in Nuclear Engineering (EMSNE), granted by ENEN, are:

- to educate students towards analytic, resourceful and inventive nuclear engineers by combining the joint state-of-the-art know-how of the participating universities;
- to train these students by making full use of the unique nuclear research and industrial facilities throughout Europe;
- to develop a common safety culture throughout Europe;

- to develop an international network of nuclear engineers and scientists by participation of students of different nationalities, by contact and collaboration with local students, and by education in several countries with different educational views, different nuclear reactor concept and technologies, and different nuclear policies.

The recognition of education requisites will certainly favor the mobility of students within European universities and the recognition of degrees can enhance mobility of graduates for PhD and for job placements in industry and research laboratories.

A significant effort has been carried out in Europe among all universities to homogenize the various systems. Following two general agreements signed in Lisbon and in Bologna [3], a curriculum constituted by a three-year bachelor program followed by a two-year master and a three-year doctorate (3+2+3 *Bologna system*) has been generally accepted and then introduced in the European countries. Furthermore, a common unit to measure student effort has also been established, to favor mobility and to simplify recognition of courses and other transfer of educational activities among different universities. The European Credit Transfer System (ECTS) has been introduced [4], in which the credit unit is equivalent to a student load in the order of 25 hours. At Politecnico di Torino it is assumed that such an effort should include a classroom activity in the order of 10 hours. It is worth mentioning that the nuclear education has profited from this framework, enhancing mobility (see Table I, for Politecnico di Torino) of students for courses, stages and final projects. In the Bologna system a semester is thus assigned a 30 credit load, leading to a 180 credit requirement for a bachelor's degree and to a 120 credit requirement for obtaining a master's degree.

Table I. Participation of master of science students to international programs at Politecnico di Torino.

Type of program	Year				
	2006	2007	2008	2009	2010
ERASMUS/SOCRATES	1	2	4	5	14
ENEN degrees	0	0	1	6	n.a.
Non-academic Stage/Final project Italy	1	2	1	1	n.a.
Stage/Final project EU	1	5	4	9	n.a.
Stage/Final project extra-EU	2	2	2	1	n.a.

Besides enhanced collaborations with many European universities, several agreements have been established with many universities in Asia and America. For instance, a European Asia-Link program involving the Royal Institute of Technology of Stockholm (KTH), Politecnico di Torino, TsingHua University of Beijing and the Technical University of Harbin has been recently brought to a successful end [5]. Within this framework, several student and young researcher exchanges have taken place among the involved institutions. Double degree programs have also been established with many universities.

The job placements of nuclear engineering graduates has seldom been a problem. Due to the strong background in basic scientific disciplines (mainly mathematics, physics and

computational methods) and to the interdisciplinary characteristics (thermodynamics and heat transfer, mechanics, material science, safety) of the programs, they can easily find satisfactory opportunities in several technical fields (mechanical, aerospace, chemical). However, in recent years, they are particularly valued in the nuclear field. Nowadays several Italian graduates have found adequate professional positions around the world, in industry, research laboratories and academia.

3. SOME STATISTICS AND AN OVERVIEW OF ITALIAN PROGRAMS

It is worth briefly analysing the evolution of the student population in nuclear engineering related programs in Italy. Over the years the interest in energy and, more specifically, in nuclear energy has been steadily growing. This is very well reflected in the evolution of the number of enrolments, presented for Politecnico di Torino in Fig.1. Other universities in Italy show similar trends.

Focusing now on the master of science program, the evolution of enrolments is reported in Fig. 2. it must be noted that around one third of the students enrolling into the master in energy and nuclear engineering undertake the nuclear oriented track. These figures clearly show the situation in which Italian universities might fall in a short time. A dramatic question is fully justified: will the system be able to maintain excellence with such a large number of students and a shrinking number of faculty?

Table II presents a collection of data to briefly characterize the Italian bachelor's degree programs related to nuclear engineering and opening a nuclear master's course for graduates. As can be seen, there is a large spread in the mathematics and physics content, as well as in the basic nuclear engineering education.

Table II. Overview of the bachelor's programs, with reference to math, physics and nuclear engineering content.

Program name	University	Math [credits]	Physics [credits]	Nuclear [credits]
Energy Engineering	Politecnico di Torino	26	16	12
Energy Engineering	Politecnico di Milano	43	12	0
Engineering Physics	Politecnico di Milano	30	30	0
Energy Engineering	Università di Bologna	21	12	12
Energy Engineering	Università di Pisa	30	24	9
Nuclear, Safety and Protection Engineering	Università di Pisa	30	24	33
Energy Engineering	Università di Roma	33	18	12
Energy and Nuclear Engineering	Università di Palermo	18	15	30

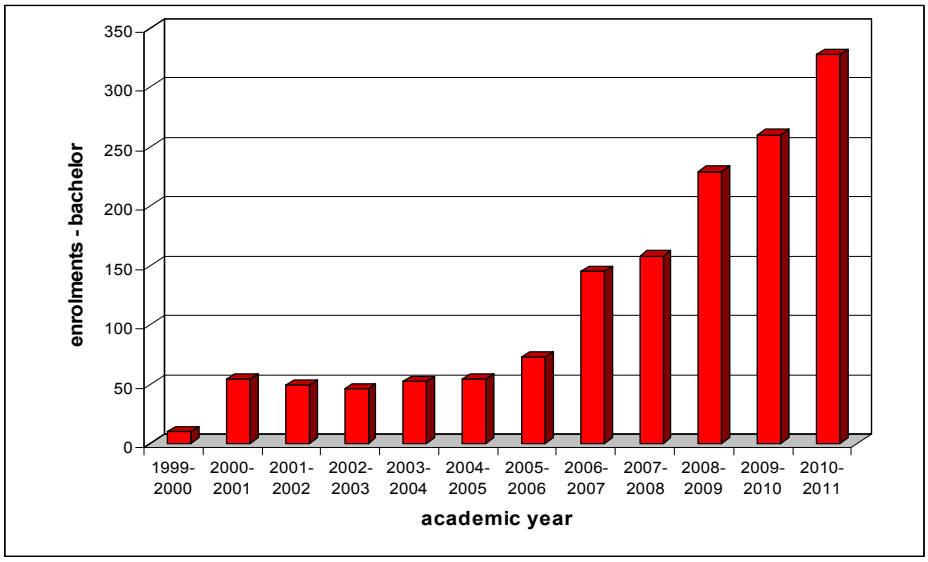

Figure 1. Evolution of the enrolments in the bachelor's program in Energy Engineering at Politecnico di Torino.

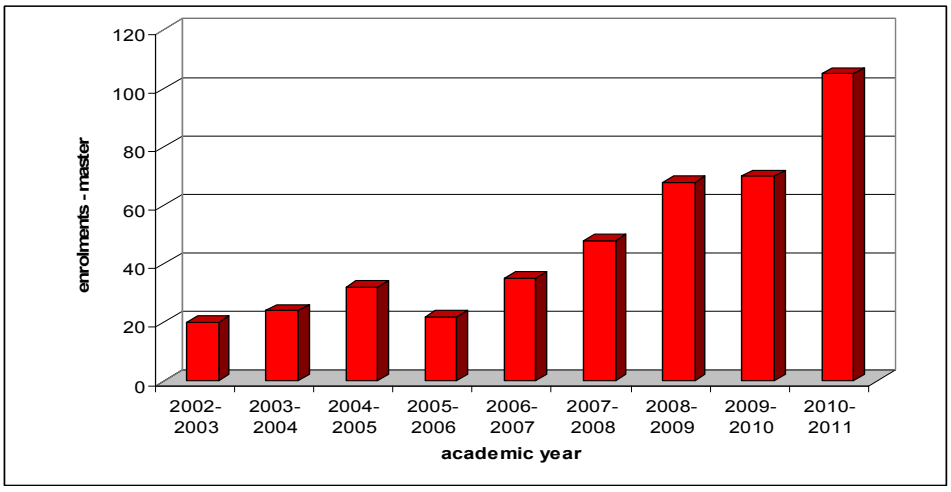

Figure 2. Evolution of the enrolments in the master's program in Energy Engineering at Politecnico di Torino.

Table III illustrates the situation of master courses with nuclear content. Also in this case there is quite a spread in the number of credits devoted specifically to nuclear engineering and, even more, to mathematics and computation.

Table III. Overview of the master's programs, with reference to mathematics and computation and nuclear engineering content.

Program name	University	Nuclear [credits]	of which M&C [credits]
Energy and Nuclear Engineering	Politecnico di Torino	80	41
Nuclear Engineering	Politecnico di Milano	85	20
Energy Engineering	Università di Bologna	42	30
Nuclear and Safety Engineering	Università di Pisa	72	6
Energy Engineering	Università di Roma	51	0
Energy and Nuclear Engineering	Università di Palermo	65	29

In Table I some data concerning student mobility are reported. The evolution of the figures clearly shows the increasing interest of master's students for an international experience, for courses, stages and final projects. Aside, one should also point out at the interest of students from other European countries for mobility towards Italian universities. This aspect is still a little thwarted by the language obstacle. However, at Politecnico di Torino a strong effort is made in order to offer courses in English. At present, over 40 credits are offered in English in the master's program.

4. MATHEMATICS AND COMPUTATION IN NUCLEAR EDUCATION

Historically, mathematics and computation courses have always played an important role in the curricula of nuclear engineering students in Italy. Nuclear programs have always been regarded in Italian technical universities as the ones characterized by the largest and highest mathematical content. This is obviously due to the importance of mathematics in the modelling of nuclear systems and of computational techniques in their simulation. The sound mathematical preparation of nuclear engineering professionals has generally been highly appreciated by industry and research centres opening interesting and stimulating technical careers even in fields other than nuclear.

The re-organization of the courses into the Bologna system has unfortunately led to a significant reduction of the mathematical and computation content of the programs. For instance, taking as an example Politecnico di Torino, in the previous five-year engineering program basic mathematics courses amounted to 50 credits, physics courses to 40 credits and mathematics and computation to 40 credits, values to be compared to 26, 16 and 47, respectively, in the present

system (see Tables II and III). Regretfully, also the typically nuclear content has undergone a drastic reduction from about 100 credits to an overall value just over 60, due to the less precise characterization of the programs, which now includes traditional energy engineering aspects too. However, all possible efforts have been made to save as much as possible the nuclear characterization, as compared to other programs.

5. THE DOCTORAL PROGRAMS: A VERY IMPORTANT ISSUE

The maintaining of qualified doctorate programs is certainly one of the key-points in nuclear education. In the past, when master's programs attracted a small number of students, PhD programs had a hard time to select good and motivated candidates. The new situation has brought in a new problems that may have serious consequences and should be now taken into due consideration. At present the number of master graduates is increasing as indicated above. However, they can easily find a job in industry and only highly motivated young fellows are now attracted by the perspective of spending a further three-year period doing a PhD, with unclear professional advantages beyond research and academia. This must constitute a concern for the future. Furthermore, all PhD programs have experienced a dramatic reduction of public funding. Hence, the problem should be tackled in coordination with non-academic research institutions and with industries, since it is certainly in the interest of all that universities maintain excellence, which can only be guarantied by highly-qualified research projects that require the contribution of PhD candidates. It appears that recently this concern has been seriously realized outside academia and proper actions are starting to be taken in support of universities.

Some data related to the past ten years are certainly interesting and deserve some comments. Since the beginning of the Bologna system at Politecnico di Torino about 80 students have graduated in energy and nuclear engineering. It is significant that after graduation ten out of them have undertaken a PhD program abroad in Europe and over ten in Italy. This high fraction clearly shows the scientific interest of graduates in the field and their motivation to undertake a scientific career. The data also demonstrates the openness to international experiences.

6. CONCLUSIONS

The analysis of the situation in the field of nuclear engineering in Italy allows to point out to some severe problems, such as the shrinking of the specialized faculty and the difficulties connected with the strong reduction of public resources. An overview of the evolution of the student population and of the nuclear oriented programs is also performed, which indicates a declining of mathematics and computation content in most nuclear programs. The role and importance of international projects is also discussed.

As a general conclusion, if the need in human resources of industry and research are to be met in the near future, one must strongly remark on the necessity of a close collaboration between industry and universities and of serious political decisions oriented to maintain competences and educational excellence in the field.

DEDICATION

This paper is generally dedicated to all assistant professors in Italian universities who are at present struggling against the stupidity of our central government. In particular, it is dedicated to our colleagues who developed enough motivations to be assistant professors in the nuclear disciplines. They all deserve to be offered better opportunities for their future than what is foreseen in the proposed bill under approval in the Italian Parliament.

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