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Keynote

THE NATIONAL INSTITUTE FOR NUCLEAR SCIENCE AND TECHNOLOGY: COPING WITH CHALLENGES OF A CHANGING WORLD

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ABSTRACT

The National Institute for Nuclear Science and Technology[1] (INSTN) stands out as a specifically nuclear-oriented higher education institution in France. Under the joint supervision of the Ministries in charge of Education and Industry, the INSTN offers advanced courses to engineers, university graduates, technicians and professionals in the different fields of application of nuclear physics, from power generation to the use of radionuclides in biology and medicine. The INSTN has now 60 years of experience in education and training which has been always driven by permanent concern to adapt its activity to the needs of the nuclear activities and programs, as well as to the evolution of the technologies and the pedagogy. The INSTN is strongly supported by the French Alternative Energies and Atomic Energy Commission (CEA) which helps the Institute to provide the best knowledge in nuclear science and expertise. Coping with the challenges of a changing world, this paper gives an overview of the INSTN's activity focusing on the education and training programs recently developed, as well as on the innovative tools that have been developed and implemented at the Institute.

1. Introduction

The 'Institut National des Sciences et Techniques Nucléaires' (INSTN) was created in 1956 when France decided to launch its civil nuclear program. Originally designed to train mainly EDF professionals and to ensure engineers acquiring a high level of scientific and technological qualification in nuclear energy, the INSTN has now set up a broad range of further education in cutting-edge disciplines (nuclear engineering, material science, health science, nanoscience) relying on the skills available at the CEA[2] and at other institutions and companies such as EDF, AREVA, for the nuclear power sector and the French TSO, the IRSN. The institute has also invested in the development of innovative pedagogy with the implementation of new distance learning courses on nuclear reactor operation[3] as well as radiation protection courses and serious games. Experimental facilities such as training reactor, accelerators, Information and Communications Technology (ICT) facilities including new generation PWR simulators, field schools for decontamination and radiation protection, as well as laboratories for the practical training in radiochemistry, radiation protection and detection and measurement (α, β, γ, neutrons and X rays). In addition, its location allows an

[1] **I**nstitut **N**ational des **S**ciences et **T**echniques **N**ucléaires (INSTN).
[2] The INSTN is administered by the CEA.
[3] Through an IAEA agreement, Internet Reactor Laboratories courses will be broadcasted via Internet to 'guest institutions' in Europe and Africa from 2016.

easy access for students and professionals to extensive facilities available at CEA laboratories.

With a permanent academic and administrative staff of 114 and the backing of some 1400 experts from national and foreign academic and scientific institutions but also from industry (EDF, AREVA, Siemens, SMEs…), regulatory bodies and hospitals, the INSTN hosted in 2015 over 6 400 trainees for continuous education and 1 100 students for academic degree programs.

Over the past years the involvement of the INSTN in education and training at an international level has strongly increased with the development of both academic and vocational programs. It is important to note that 30% of our students are international students. A large panel of international courses lasting one to two weeks has also been implemented on a yearly base and covers neutronics, thermo-hydraulics, nuclear materials, principles and operation of nuclear reactors as well as fuel cycle and reactor dismantling topics. In addition, international tailored made trainings have been developed on demand and delivered at the 5 INSTN premises to satisfy the specific needs of the nuclear sector. INSTN experts have also provided training and support in various fields, including radiation protection and radiopharmacy in France or abroad. At an European level, the INSTN has strengthened its cooperation with universities and companies with an important involvement in several European projects aiming at the development of nuclear education and training in nuclear engineering (ENEN III) , radiation protection (ENETRAPII) as well as on radioactive waste (PETRUS III) and the enhancement of safety culture (NUSHARE).

To tackle the growing need for a high level education and training in the nuclear field, the INSTN developed different training modalities, including widening the scope of its initial and continuous training offer. The following sections will present each training mode and illustrate some of the most fruitful examples of actions undertaken at a national and international level.

2. Initial training

Over 40 academic degrees, including Higher Technician Diplomas, Bachelors, Masters and engineering degrees are issued by the INSTN.

Higher Technician Diploma (BTS) in radiation protection
This course teaches students about the requirements involved in working in an irradiated environment. They learn to implement all the techniques for radiation control and to apply radiation and contamination protection rules in compliance with applicable legislation. Students are selected on the results of a knowledge test in mathematics and physics. A B2 level in French is required for attendance.

Masters and engineering degrees
More than 30 Master degrees, delivered in cooperation with Universities and Engineering Schools, are mainly addressed to M2 students and cover a wide range of topics developed within CEA research laboratories such as nuclear energy (fission and fusion), functional and structural engineering of proteins, radiobiology, materials for structures and energy, nanophysics, nanobiology and nanobiotechnologies, innovation and technology management, astrophysics, radiation protection… Most of these Masters are taught in French but a few of them are taught in English. All Masters are open to foreign students representing around 30% of the INSTN student population (Figure 1), coming from about 60 countries, mainly non-EU (Figure 2).

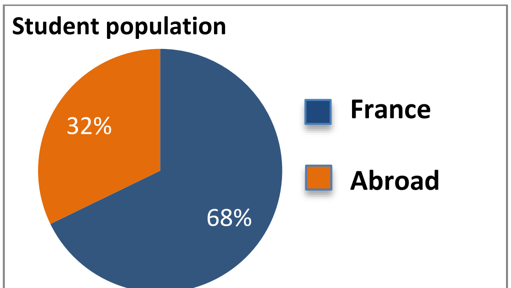

Figure 1

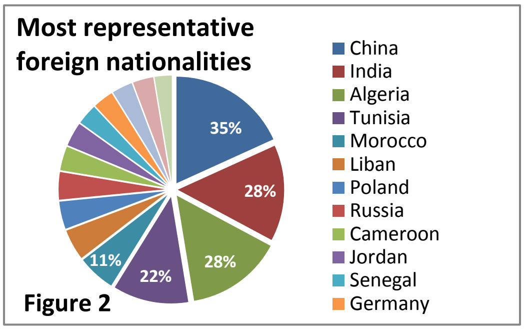

Figure 2

INSTN main pedagogical efforts are focused on the design and implementation of specifically nuclear-oriented educational programs as required for the maintenance and development of the nuclear sector. Some of them are exclusively accredited by the INSTN (Figure 3). They include a medical physicist degree (DQPRM) as well as specialities for medical doctors and radiopharmacists, in accordance with European and French directives on health, and two specialised educational programs in nuclear engineering: the Master in nuclear energy and the "Génie Atomique" (nuclear engineering) course.

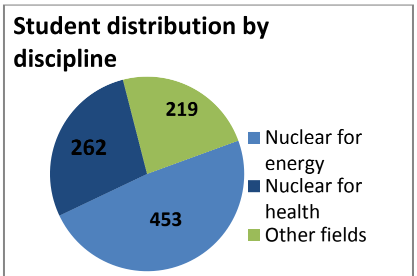

Figure 3

The **Master in nuclear energy** is a two-year program fully taught in English by a large consortium of universities, engineering schools and key industrial partners such as AREVA, EDF, ENGIE. It aims to teach both French and international students the principles and knowledge required for the nuclear industry. The M1 is aimed at acquiring compulsory "Core Syllabus" of a general basic knowledge in almost all the domains in nuclear energy. The five Majors offered at the M2 level cover a wide variety of careers in the nuclear industry as either experts or managers in fields such as:

- Nuclear reactor physics and engineering
- Nuclear plant design and construction
- Operation and Maintenance
- Decommissioning and waste management
- Fuel cycle

The programme also aims to prepare students for a career in research and education for those continuing with a PhD scheme.

The **Génie Atomique** (Nuclear Engineering) is a specialized engineering degree (one year after a master degree in physical science) delivered by the INSTN and aims at educating high skilled engineers in the nuclear engineering field. Students learn basic sciences and technology and their application to research, design, operation and optimization of nuclear power plants. The curriculum lasts one calendar year and is organized in 2 phases:

- ➔ A 7 month academic part with courses, conferences, exercises and laboratory sessions so as to allow students to acquire a systemic view in the nuclear engineering field
- ➔ A 5 month internship in research centres, universities, industry in France or abroad to apply the knowledge and concepts acquired during the first phase to real research or industrial situations.

This educational scheme is unique in France in terms of number and volume of courses (more than 500 hours) and facilities involved in the training. Since its inauguration in 1955, INSTN has graduated more than 5000 nuclear engineers. Most of them had or have top positions in all major organisations of the French and International nuclear sector. As illustrated in Figure 4, the higher student enrolment occurred at the creation of the curriculum, between 1958 and 1970, when France decided to launch the nuclear civil program. After 1970, about 60 to 100 students per year enrolled in the programme in relation with the French and world perspective for the nuclear sector. Most recently, an increasing number of foreign students attended the “Génie Atomique” course, mainly from China and North-Africa (Figure 5).

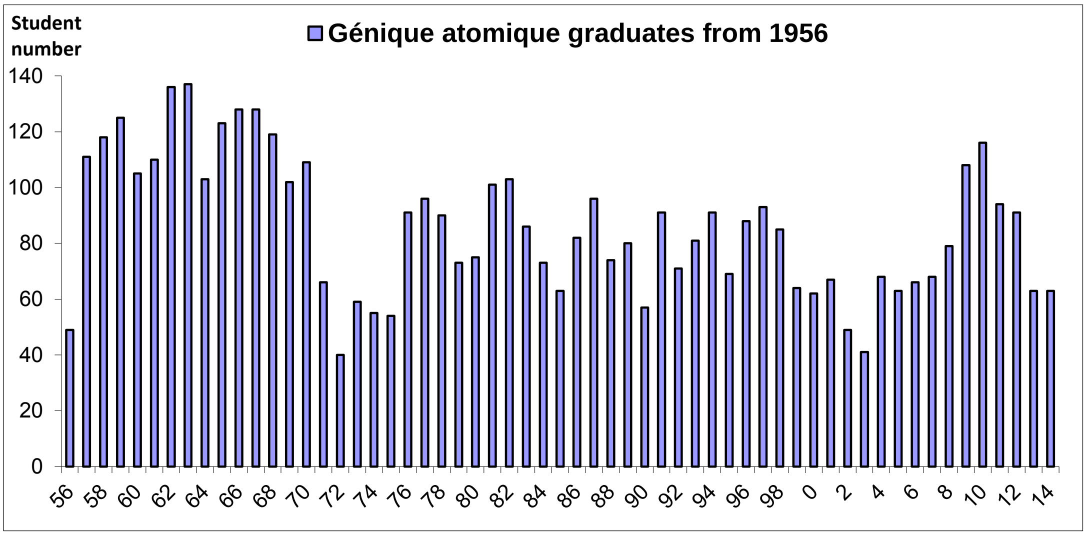

Figure 4

Year	Foreing students	%	Countries of origin
2010-2011	23	31	11 Tunisia, 4 China, 2 Belgium, 1 Spain, 1 Canada, 1 Cameroon, 1 Russia, 1 Malaysia, 1 Vietnam
2011-2012	11	15	6 Tunisia, 3 China, 1 Lebanon, 1 Netherland/Japan
2012-2013	12	26	6 China, 2 Italy, 1 Belgium, 1 Czech, 1 Morocco, 1 Bahraini
2013-2014	8	17	4 China, 2 Morocco, 1 Spain, 1 Tunisia

Figure 5

3. Continuous professional training offer on catalogue

Continuous education represents another important panel of the INSTN activity aimed at up-dating knowledge of those who already have a strong background in an applied field (professionalization program) or in an initiation scheme to new techniques (specialization program). Training sessions, lasting from a few days to a few weeks are organized all year long for professionals, researchers or qualified technicians. The INSTN offer covers all the field related to nuclear engineering, including nuclear fuel cycle, radiation protection, imaging in nuclear medicine, but also micro and nanotechnologies, new energy technologies as well as soft skills such as patenting and intellectual property rights. All the INSTN vocational training is implemented under quality assurance procedures: the INSTN has an ISO 9001 certification since 2001. The INSTN course catalogue presently includes an offer of more than 200 trainings taking place at the INSTN premises and are mainly provided in French even if a growing number of these courses are now made in English, specifically for the following topics:

- Principles and operation of nuclear reactors
- Neutronics for Light Water Reactors
- Thermal hydraulics for Light Water Reactors
- Operation and safety of pressurised water reactors
- Criticality-Safety
- Nuclear fuel cycle
- Nuclear materials for pressurised water reactors
- Metallurgy and properties of Zirconium alloys for nuclear applications
- Introduction to the use of plutonium
- Nuclear waste management
- Nuclear facility dismantling experience
- Generation IV: nuclear reactor systems for the future
- Basic operations on nuclear reactor

Overall, in 2015 the INSTN delivered 656 training session for a total of 3666 training days to more than 6400 trainees. Despite the economic crisis, the difficult post-Fukushima context and the debates on the energetic transition at the COP21 conference and inside France, the number of training days delivered in the nuclear field remain constant. Over 86% of the training delivered was in the nuclear field, with 8% being international and 31% of them delivering accreditation to trainees (Figure 6). The need of training in radiation protection and nuclear for health is noticeable with more than 50% of the total training delivered (Figure7).

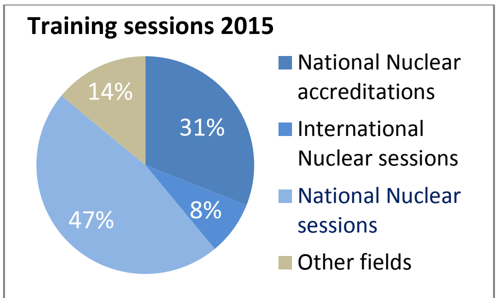

Figure 6

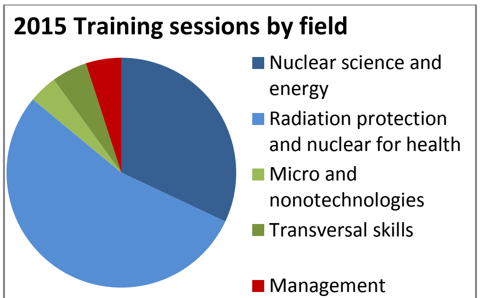

Figure 7

For PhD students and young researchers a dedicated international offer of six advanced courses has also been developed. Each course, lasting one week, is dedicated to a specific aspect of nuclear reactor design and operation:

- Thermal Hydraulics and Safety,
- Nuclear Fuels for Light Water Reactors and Fast Reactors,
- Reactor Core Physics and Monte Carlo Methods,
- Materials for Nuclear Reactors, Fuel and Structures,
- Nuclear Fuel Cycle and Reprocessing,
- Nuclear Waste Management.

From 2015, 2016 in the frame of an agreement with the IAEA, an Internet Reactor Laboratory (IRL) project is being implemented. Practical work via Internet on the French research reactor ISIS will be made available to countries having no installed facilities but need to train students and professionals in experimental nuclear physics and reactor operation. The IRL creates a virtual reactor in a remote location via an internet link. Using an advanced videoconference system connected to the supervision system of the reactor , reactor data and video signals are sent over the internet to the training institution, where a real-time display of the reactor activity and parameters is available for the trainees. Trainees can interact to “conduct experiments” by asking the reactor operators to change reactor settings and seeing the real-time displays change accordingly.

4. Training on demand

The INSTN also designs, implements and organizes on demand basic to advanced, flexible, tailored trainings in relation with its expertise. Those customized national or international trainings can be delivered either at the INSTN premises or at clients’ location. Examples of training on demand delivered at the INSTN includes ‘Safety Culture trainings’ for Rolls Royce (FR), Energetic Transition and Sustainable Development for Renault (FR), Operation of Pressurized Water Nuclear Plant for EDF (FR), as well as Principle and Operation of Nuclear Reactors for ENEL (IT) or Practical training on ISIS reactor addressed to university master students from Sweden and Finland. These trainings, lasting from 2.5 days to 2 weeks, are mainly dedicated to provide new or up-dated skills and knowledge to trainees.

Moreover, the INSTN has also been active in serving newcomers in nuclear to develop their own nuclear engineering educational program. In 2011 and 2015, two successive 12 and 8 week “Train the Trainers” program, to train future trainers in science and technologies have been defined and delivered for university professors and researchers on the demand of Polish Universities. In addition to conferences and lectures, technical visits of CEA as well as industrial facilities have been organized including the visit of the EPR construction site in Flamanville (FR), a fuel reprocessing unit in La Hague (FR) and a nuclear power plant in Doel (BE). Shorter sessions for tutoring decision-makers to address energy-related issues, have also been organized.

Finally, INSTN experts have supported the creation of several programs at customer’s locations such as the development and implementation of the Master on radiation protection (University of Kenitra) as well as a vocational training offer on radiation protection in Morocco or the development of radiopharmacy initial training in Tunisia. An introductory course on nuclear energy has also been provided to students of the National school of engineers of Tunis (ENIT) as well as assistance for the development of human resources to the Tunisian electrical supplier STEG. The INSTN also trained students from the Saudi King Abdullah University and plays an important part in the preparation of a French answer to a possible request from proposals issued by the South African Government for the implementation of a nuclear program.

Besides, the INSTN organizes also courses exclusively intended for specialists from foreign countries under the International Atomic Energy Agency (IAEA) umbrella.

5. Involvement in EU projects

The INSTN is strongly committed to the development, sharing and harmonization of educational skills in nuclear science and technology, in particular at the EU level. The INSTN has been awarded the extended ERASMUS University Charter and, as declared in its ERASMUS Policy Statement, promotes mobility of students and teaching staff to favor scientific exchanges, cooperation and dissemination of best practices. Moreover, the INSTN is open to multilateral cooperation with higher education institutions and enterprises and is involved in several European projects aiming at implementing nuclear education and training on different topics ranging from nuclear engineering (ENEN-III), radiation protection (ENETRAP) and waste management (PETRUS III) to the enhancement of the nuclear safety culture (NUSHARE).

The INTSN is also a leading member of the European Nuclear Education Network (ENEN) since its creation in 2003.

6. Conclusion

The INSTN is the French key player in education and training on nuclear engineering and radiation protection since 1956. Aware of the growing educational and training needs of the nuclear sector, the INSTN has been diversifying its training offer to better respond to national and international challenges.

Today and tomorrow, the INSTN offers a large scope of high level educational programs, mainly at the Master level, as well as vocational training open to French and foreign firms.

The INSTN tackles also specific training needs expressed by countries interested in the development of nuclear engineering and knowledge in nuclear energy of nuclear medicine.

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Managing the nuclear supply chain

OPPORTUNITIES FOR BUILDING NUCLEAR COMPETENCES AND THEIR EXPLOITATION: A PRELIMINARY ANALYSIS

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ABSTRACT

The aim of this work is to provide an analysis made on training opportunities offered in the nuclear energy sector and how these have been used, compared to the potential competences that are needed. The analysis reflects experiences and challenges gathered in the education and training project GENTLE, interactions and dissemination experiences of the NUGENIA+ project and activities of ENEN. It is based on the "pyramid of competences" as discussed within the EHRO-N and OECD reports. The focus of the analysis is on the training proposed for continuous professional development, as well as on the access to nuclear research infrastructures granted to MSc and PhD students. The low responses received from the nuclear energy sector on surveys, launched both within NUGENIA+ and GENTLE, concerning training needs for the professional development, as well as the relatively low response in the professional training offered within GENTLE, have triggered a deeper assessment of the situation. For this purpose hypotheses on training needs as individuals and nuclear employers could express them have been formulated and criteria for the shaping of trainings are proposed. Moreover, for comparison the access to nuclear research infrastructures granted to MSc and PhD students through the GENTLE project is presented, for which a large interest has been observed.

1. Introduction

Despite the debates and controversial decisions on the use of nuclear energy, the developments foreseen in the coming decades in the nuclear energy sector require high-level expertise and competences for the design, new build, operation and decommissioning of nuclear reactors and facilities as well as for the management and disposal of the nuclear waste. The attractiveness of the nuclear energy sector for talented professionals and students depends upon a comprehensive recognition that this sector is in expansion and that it offers attractive career pathways. From a global prospect, signs for a growing nuclear energy sector are uncertain, in particular in the OECD countries. Nevertheless, observing the trends at regional level it turns out that there are regions (e.g. several countries in Asia) where nuclear energy is considered as an expanding part of the energy mix and new reactors are planned, giving a positive picture of a growing sector. In other regions, as e.g. Europe, the situation is very diverse. Some European countries have excluded nuclear from their energy policy, some are phasing out while some countries are building or planning new nuclear power plants. In such a situation, a clear positive trend for an expansion of the nuclear energy sector is not immediately recognised. However, as stressed by international organisations as IAEA [1, 2], OECD-NEA [3] and SNETP [4], a variety of nuclear knowledge, competences and expertise for these different approaches are equally needed and recommendations have been formulated in order to support the building and keeping human capabilities and expertise. The international organisations have recommended to make an analysis on the education and training needs, to provide accordingly to this analysis opportunities both in the academic domain and for professional development, to carry over the accreditation and certification culture into the vocational training sector, to foster networking among industries, universities and research centres, and to draw and put in practice attractive career opportunities.

In response to these recommendations, the European Commission launched the European Fission Training Schemes (EFTS) in several nuclear areas [5]. In this context, the "Graduate and Executive Nuclear Training and Lifelong Education" (GENTLE) project was initiated in 2013. GENTLE provides grants for mobility and training of students as well as training for professional development [6, 7].

Further examples of EFTS projects where the European Nuclear Education Network Association (ENEN) is involved are the NUSHARE project, for sharing and growing nuclear safety culture competence (2013 – 2016), the ENEN-RU-II, a bilateral cooperation with Russia in Nuclear E&T and Knowledge Management (2014 – 2017), and the PETRUS III project, the Program for Education, Training, Research on Underground Storage (2013 – 2015) [14].

In the following paragraphs the achievement and evolutions of the GENTLE project are analysed together with the activities performed in the Nuclear Generation II&III Association plus (NUGENIA+) project on interactions and dissemination experiences. The activities of the European Nuclear Education Network (ENEN) are also described.

2. The pyramid of competences and associated education and trainings

Categorisation of the competences in the nuclear sector can be used as an indicative guide for the identification of needed education and training programs. As shown in figure 1, there are different approaches for categorisation [3, 10, 11].

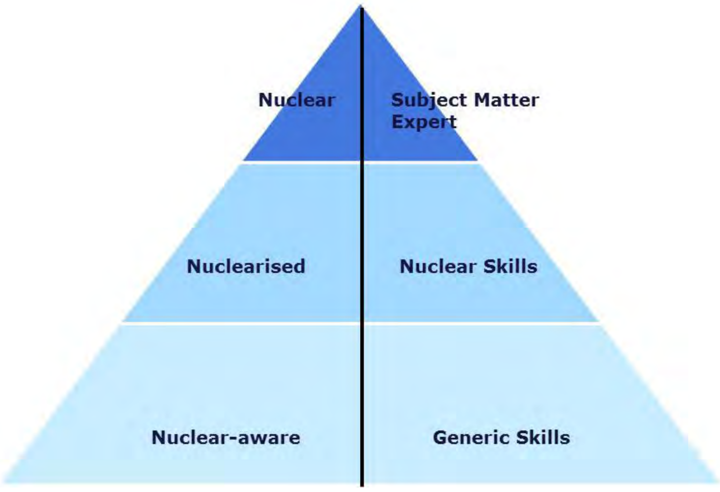


Fig. 1: Generic competence categorisation [3, 10] (left hand of the triangle) and country specific categorisation [11] (right hand of the triangle)

Hereafter, the meanings of the category of competences, as reported in figure 1 are briefly summarised:

Base of the competence pyramid:

- *Nuclear-aware*: Require nuclear awareness to work in the nuclear industry (electricians, crafts and support personnel).
- *Generic skill*: Require nuclear awareness training (nuclearisation) to adapt to the rigorous quality and safety standards (engineers, project and programme managers).

Middle part of the competence pyramid:

- *Nuclearized*: Formal education in non-nuclear area and need to acquire knowledge of the nuclear environment.
- *Nuclear skills*: Developed nuclear specific knowledge and competences. Must have a documented combination of qualifications.

Upper part of the competence pyramid:

- *Nuclear*: Specialised formal education in nuclear subjects.
- *Subject matter expert*: Developed nuclear specific knowledge and competences. Technically and often fundamentally important to the future of the sector (principal or chief scientists, engineers, technologists, senior fellows, experts in nuclear specific fields.

Even if there is not a complete correspondence between the generic and the country specific categorisations, as shown in the next paragraph the GENTLE education and training activities have addressed the categories of "*nuclearized*" and "*nuclear*" or from the country specific perspective the categories "*generic skills*" and "*nuclear skills*".

2.1 Objectives and activities of the GENTLE project

The aim of GENTLE is to create a sustainable lifelong learning programme in the field of Nuclear Fission Technology that meets the needs of relevant stakeholders (industry, research, regulatory and TSO organizations). This is done through three main pillars i.e. (1) the mobility grants for students; (2) the inter-semester courses; and (3) the professional education program [6, 7].

The mobility grants are dedicated to the mobility of students within Europe to allow the improvement of their *nuclear skills*. The grants are for students at bachelor and master level and for external research activities within PhD projects. The students have the opportunity to apply for open call from the participating organisations, but also propose themselves research projects and internships with the various GENTLE partners.

The student mobility grants can be considered as training opportunities for the competence category of "*nuclear*" / "*nuclear skills*" and as will be discussed in a next paragraph. This activity of the GENTLE project experienced a high interest rate.

The *inter-semester courses* are offered for graduate and postgraduate students on special topics that are generally not part of academic programmes. As for the mobility grants, also this training is addressed to improve the competence for the category "*nuclear*" / "*nuclear skills*". In table 1 the topics and locations of the courses are shown. The locations have been selected among the GENTLE partners in order to deliver the highest level of expertise in the topic and to allow for proper hands-on trainings, which are an essential part of the inter-semester courses.

Inter-semester course title	**Course responsible, location**
Nuclear Data	Joint Research Centre, IRMM, Geel Belgium
Nuclear Safeguards and Security	SCK•CEN, Mol, Belgium
Reactor techniques	Budapest University of Technology and Economics, Hungary
Thermal-hydraulics phenomena	Lappeenranta University of Technology, Finland
Nuclear Fuels	Joint Research Centre, ITU, Karlsruhe, Germany
Nuclear Waste Management	Karlsruhe Institute of Technology, Germany
Decommissioning	University Manchester, United Kingdom

Tab 1: List of inter-semester courses organised within the GENTLE project

The *executive professional education program* was designed in order to address the competence category of "*nuclearized*" / "*generic skills*" for professionals with a university degree in a STEM area. A five module series, each module lasting two weeks, targeted to individuals who wish to enhance their knowledge of nuclear reactors and fuel cycles was proposed (see table 2). The course was designed as classroom teaching with hands on training.
Despite a wide dissemination of the announcement of the professional education program, it received very little interest. Due to this fact and before deciding a next step, an evaluation has been done by taking also into account the experiences of NUGENIA+ and ENEN.

Name	Module responsible, location
Understanding nuclear power	Technical University Delft, The Netherlands
Producing energy with nuclear reactors	Karlsruhe Institute for Technology, Germany
Nuclear fuel: from ore to waste	Joint Research Center, ITU, Karlsruhe, Germany
Conditions for societal justification of nuclear energy	SCK•CEN, Mol, Belgium
Management systems	Polytechnic of Milan, Italy

Tab 2: Modules and modules responsible for the GENTLE professional course

2.2 Education and Training activities within ENEN

The ENEN association contributes to the EFTS programs putting together joint efforts in specific areas where a shortage of skilled professionals has been identified [5, 14]. The current programs are:

- NUSHARE – *Project for sharing and growing nuclear safety culture competence*: focus on policy makers; regulatory authorities; industry (Jan. 2013 – Dec. 2016)
- ENEN-RU-II - *Cooperation with Russia in Nuclear E&T and Knowledge Management*: mirror project by ROSATOM and MEPhi (June 2014 – May 2017)
- PETRUS III - *Program for Education, Training, Research on Underground Storage*: addressing mainly the radwaste agencies (September 2013 – August 2015)
- CORONA II - *Regional Center of Competence for VVER Technology and Nuclear Applications*: focus on VVER personnel training (December 2011 – November 2014.

The new recently started project ANNETTE aims to maintain and develop education and training in the different nuclear areas of nuclear safety/engineering, radiation protection, waste management and geological disposal, nuclear safety culture with special attention to continuous professional development, life-long learning and cross border mobility. The practical implementation of an industrial cross border mobility using the ECVET system will be tested and analysed. For the first time a transition from science to technology occurring in the fusion research environment integrates the E&T effort on the fission side with common actions related to fusion.

2.3 Training within the NUGENIA+ project

A one activity of the NUGENIA project is the establishment of the NUGENIA School with the aim to maintain present knowledge of nuclear workforce and transfer it to young scientists & newcomers to nuclear field. In practical terms, the school will organise training courses / workshops for junior staff of NUGENIA member organisations.
The training / workshops will be focussed on specific technical issues, and will be organised in close collaboration with existing nuclear E&T networks, projects, and training academies in order to avoid duplication of efforts.

2.4 Common issues experienced within GENTLE and NUGENIA+

According to the recommendations as discussed in paragraph 1, a mapping of the education and training needs has been performed both in GENTLE and in NUGENIA+ through two distinct surveys.

The GENTLE survey, conducted in the year 2013 was focussed on the professional education program and was aimed at collecting feedback on the format and the content of the program [13].

The NUGENIA+ survey, conducted in the year 2015 was aimed at identifying education and training needs by the NUGENIA members.

Both surveys were conducted in electronic form and were distributed to a wide European nuclear energy community through different channels as e.g. FORATOM, ENS, etc.

Even after repeated requests, the number of feedback received was very limited: twelve answers were received for the GENTLE survey and two answers from the NUGENIA+ survey.

The answers received showed that there was in general interest toward the GENTLE program (with different emphasis on the modules and the format) and for what concerns the two responses from the NUGENIA+ survey, they indicated the need of training on very specific topics.

A specific analysis on why the responses received was so low, has not been done. However, it has been decided within the ANNETTE project to re-launch a survey in order to capture the state-of-the-art in education and training (E&T) and vocational (VET) learning activities in order to map the activities and to identify potential duplications or gaps.

Given this situation, an evaluation on different scenarios on how to proceed with the training offers has been done and discussed in the next paragraph.

3. Trainings for professional development compared to potential needs

To capture the multifaceted picture concerning the relationship among individuals, nuclear employers and training providers a close interaction between these three entities would be needed. However, since an effective and satisfactory interaction could not yet be established, the evaluation herein given is based on a number of assumptions that have been formulated considering the competence pyramid of figure 1 and focussing on the categories "*nuclearized*" and "*nuclear*" (or "*generic skills*" and "*nuclear skills*").

In this framework, it has been assumed that "non-nuclear professionals with a University degree" that want enter the nuclear field would correspond to the category "*nuclearised*" (or "*generic skills*") while "nuclear professionals" that are interested in a professional development in the nuclear field would correspond to the category "*nuclear*" (or *nuclear skills*") [8]. For both cases nuclear education and training is of relevance. However, the non-nuclear professionals would need to acquire basic knowledge on nuclear energy and technology and would attend introductory courses. Most probably, the attractiveness of the courses would be high if they have a blended character, i.e. e-learning, class-room and hands-on training; deliver a recognised certificate and are within an affordable financial framework (it is here assumed that non-nuclear professionals would self-invest in their professional development); while the duration of the courses might not play a major role.

As for the training needs for professionals that are already active in the nuclear field and want to develop their career, the criteria for making the courses attractive would be most probably the following: high thematic specialisation of the course; short-term duration; course certification; and reasonable financial framework (in this case the investment could be done either by the employer or by the individual). The e-learning component of the course might be less relevant.

As discussed previously, it was necessary to formulate assumptions of training needs of nuclear employers. This has been done using the competence pyramid and differentiating between employers with a developed competence framework and associated own nuclear training, and employers that do not organise own nuclear training but want to "nuclearize"

their employees. Even if this distinction is not exhaustive to describe the European nuclear employers and related sectors it is considered useful to have a preliminary understanding of their training needs. In fact, it was assumed that nuclear employers with own training programs and facilities, in principle, might be interested in experts for lecturing at their training courses and / or are interested to short-term problem solving, thus very specific, trainings. On the other hand those employers that want to nuclearize their employees or do not have own training programs might have interest in short-term courses on specific topics and open e-learning courses on generic topics. It has been assumed that these employers do not give a high priority to certification.
Finally, nuclear training is provided in European Member States by different entities. Within the GENTLE project, for instance, the training courses have been organised in collaboration between universities and research centres. However, there are relevant differences between these two training providers which can be summarised as follows.
The universities are engaged in delivering accredited and certified Bachelor and Master courses in the nuclear energy field. Most universities organise these course in class-room style (including hands-on training) and some blend them also with e-learning. Universities promote and / or host PhD students and participate to research projects. Finally, Universities are also involved, through direct organisation or by sending their experts, into seminars, summer-schools, inter-semester courses and workshops.
Research centres with nuclear infrastructures are engaged in hosting students (MSc, PhD) and professionals for various purposes as e.g. hands-on training with nuclear materials, dissertation work, etc. Similarly to the universities, research centres are involved in research projects and organise and or experts/lecturers participate to universities courses, workshops, seminars and summer-schools.
As shown in the next paragraph, taking the example of the GENTLE mobility grants, a well-established relation between universities and research centres exist, providing education and training opportunities to students.

4. Preliminary results from the GENTLE mobility grants

The data presented here on the GENTLE mobility grants are preliminary, since these grants will be assigned until end of the year 2016. Before starting effectively with the grant assignments, the rules and the process for quality assessment of the proposals had to be established [11]. Since the year 2013, more than 50 students enrolled in European Universities received a GENTLE grant for the duration of one to twelve months to access research infrastructures belonging to the GENTLE partner institutions. Figure 2 reports the number of these students per country of the sending universities. Until January 2016, universities of thirteen EU member states and Switzerland used the GENTLE grants. Most students that have received a GENTLE grant were enrolled at French or Italian universities.

Access to the grants can occur either through application to open posts published on the GENTLE webpage [6] or through the proposal of own research projects. The GENTLE consortium counts thirteen member institutions across Europe and Switzerland. As shown in figure 3, until March 2016 all GENTLE partners but two hosted at least one GENTLE students. The highest access rate was observed for JRC-ITU, SCK-CEN and KIT, most probably because these three research organisations offer a much diversified research portfolio in combination with highly nuclearized research infrastructures.

An overview on the topics currently dealt with by the Students during their access to the GENTLE research infrastructures is given in figure 4. The topics are Reactor Physics (RP), Thermal-hydraulics (THY), Nuclear Data (ND), Nuclear Fuel (NF) and Fuel Performance Codes (FPC), Nuclear Waste (NW), Generation IV reactors (Molten Salt Reactor (MSR) and Liquid Metal Fast Reactors (LMFR)), Particle accelerators for Accelerator driven systems (PA-ADS) and fundamental research of actinide science. The time spent on these topics was quite different with the highest duration on Reactor Physics, Nuclear Data, Nuclear Fuel and Nuclear Waste. It can also be noticed that specific topics as Nuclear Decommissioning, Lifetime Extension, Small Modular Reactors have not been proposed in the portfolio until now.

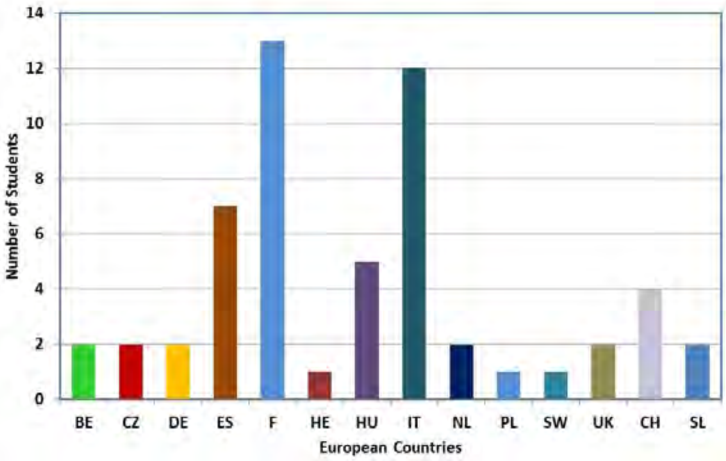


Fig. 2: Number of students enrolled in European Universities using the GENTLE grants.

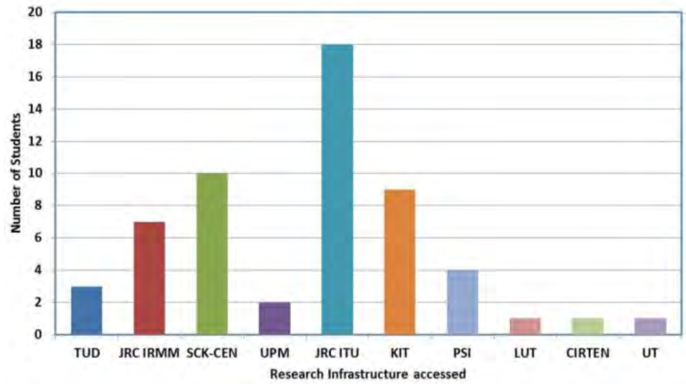


Fig. 3: Number of Students accessing the research infrastructures of the GENTLE consortium.

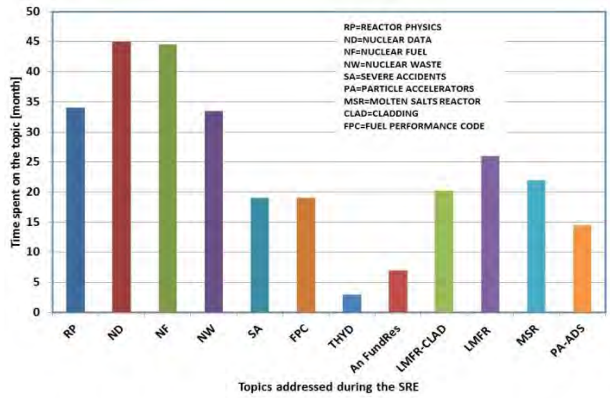


Fig. 4 a: Topics addressed during the GENTLE mobility grants

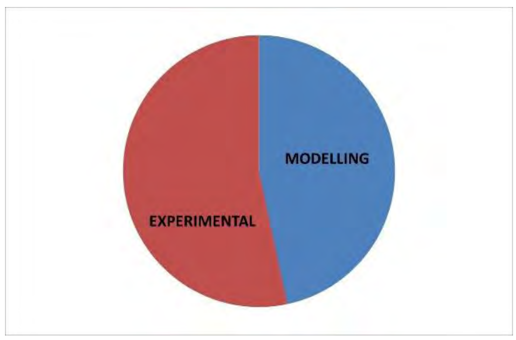


Fig. 4 b: 40% of time on modelling and 60% on experiments

The GENTLE mobility grants have proven to be an effective tool to improve "*nuclear*" competences. Even if we do not have a feedback on the professional career of the students (if they remain in the nuclear sector), the experience gained by the students through this tool has been considered as valuable and will be part of their qualifications. It is therefore recommended to continue this type of activity also in future EFTS.

5. Discussion

As mentioned previously, within the GENTLE project and the NUGENIA + project it has been difficult to establish an effective network with the nuclear energy sector in order to define education and training needs to keep and develop human capacities in the nuclear field. Furthermore, within the ENEN Association the overall offer of European education and training is given, but the match between demand and supply of education and training hasn't been assessed.

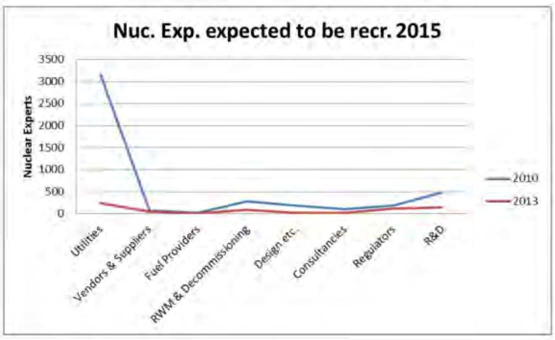
In the present work, an attempt to identify criteria for the needs has been made with reference to the pyramid of competences. However, this assessment is preliminary since the pyramid of competence can be built in different ways (the generic classification vs. the country specific classification).

Moreover, a further aspect that has to be taken into account is that needs for nuclear training expressed either by the individuals or by the nuclear employers can change due to nuclear events, political decisions, etc. In turn, these changes have an impact on the planning of training courses, their contents and tools used for their implementation.

Results given in the EHRO-N report [9] are an example on how drastic changes can occur after an important event such as for example the Fukushima accident. The EHRO-N report summarises the results of a survey performed in the year 2013 on the number of students accessing nuclear energy courses in European universities and on forecasted needs of nuclear experts in European nuclear companies and compares it with a similar survey conducted in the year 2010. Focussing first on the forecasted needs of nuclear experts in European nuclear energy companies, as shown in figure 5 the results of the surveys confirm expected trends before and after Fukushima.

In the year 2010, the nuclear utilities for instance were expecting to hire more than 3000 nuclear experts by 2015. This number dropped to less than 500 in the 2013 survey. Showing how the expectations of the utilities have changed within a timespan of three year.

Similarly, it can be assumed that the interest of European professionals to enter the nuclear field has changed and therefore "*nuclearisation training*" courses as they were planned before the Fukushima event might have become less relevant.



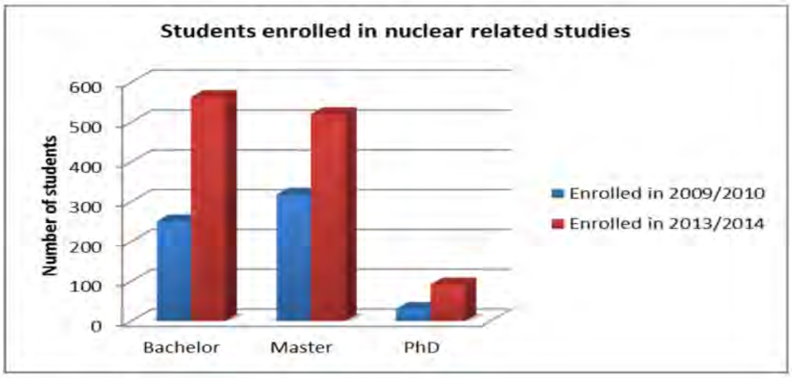
Source: EHRO-N

Fig. 5: Nuclear experts expected to be recruited by 2015; expectations in 2010 (blue line) vs. expectations in 2013 (red line) Source: EHRO-N [9]

Despite this changing situation, it is assumed that the concerns expressed by OECD-NEA, IAEA, SNETP, EC on the necessity to maintain nuclear competences are still valid. In order to understand how to attract talented professionals and students to the nuclear field some pro-active initiatives are needed.

As an example, within the GENTLE project it has been decided to re-design the professional education program into a Massive Open Online Course (MOOC). The GENTLE MOOC on "understanding nuclear energy", is a six-week course and is currently under preparation. The online start is foreseen on the EdX platform in October/November 2016.

A further result of the EHRO-N survey was the number of students accessing nuclear energy courses in European universities. These results are summarised in figure 6 and compared with a similar survey done in the year 2009.



Source: EHRO-N

Fig. 6: Nuclear engineering students and students following nuclear related subjects that started in year 2009/2010 and 2013/2014 in the EU-28. Source EHRO-N [9].

As shown in figure 6 the number of students that showed interest to nuclear related matters increased from 2009 to 2013. This trend is in line with the high interest that the GENTLE mobility grants gained. Moreover, the mobility grants showed how effective the relation between universities and research centre is in providing training opportunities for students.

However, a different approach seems to be needed for the interaction between universities and research centres concerning training initiatives for professional development. This approach should include the adoption of accreditation formats recognised by the entire nuclear energy sector and a closer partnership with the nuclear industry in order to define a common strategy for the development of human competences in the nuclear field.

6. Conclusions

This paper provides a preliminary analysis of the training opportunities that can be provided through the GENTLE project and their exploitation, as a relevant example of a training action in Europe. The focus has been set on the professional development and the access to nuclear research infrastructures opportunities for students.

Activities on the GENTLE mobility grant programme was highly appreciated and successfully implemented.

On the contrary, difficulties have been encountered in implementing training programs for professionals. These difficulties might be due:

- to the fact that nuclear energy is still a controversial issue, and might therefore appear less attractive for talented professionals compared with other energy sectors;
- to career pathways that are not clearly established with a view to the long-term evolutions by the major European nuclear energy sector, even if there is a wide agreement on the fact that human competences in the nuclear field are definitely needed in the next decades.
- to a not yet satisfactory partnership between nuclear employers and education and training providers.

In order to keep the positive trends observed within the GENTLE mobility grants and to improve the trends in the area of professional development training, a number of pro-active initiatives are hereafter suggested, where the ENEN Association, NUGENIA and other international organisations could play an important role:

- Open the dialog with European stakeholders on nuclear energy and associated needs in order to identify shortcomings and possibly correct them and to improve the mutual understanding on the importance of developing nuclear knowledge, skills and competences.
- Establish specialised (sectorial) partnerships between education and training providers and nuclear employers for a deeper and continuous collaboration on nuclear competences and associated training needs.
- Integrate in the European approach the renewed interest that can be observed in different regions of the world for nuclear energy and innovation challenges as long terms strategic efforts.
- Develop exchange programmes for students/young researchers within the European Union and with countries that have a dynamic nuclear program
- For a wider outreach: introduce e-learning modules, MOOCS, webinars etc. on nuclear energy and innovation.

Acknowledgement: This work has been performed within GENTLE CSA (nr. 323304) of the FP7-EURATOM-FISSION programme in the area Fission-2012-5.1.1 and the JRC-ITU work package In-F. A special acknowledgment goes to the GENTLE consortium: Delft University of Technology; Budapest University of Technology; CIRTEN; Joint Research Centre; Karlsruhe Institute of Technology; SCK•CEN; University of Madrid; University of Manchester; University of Tartu; Paul Scherrer Institute; Lappeenranta University of Technology.

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DEMONSTRATING COMPETENCE AND CAPABILITY IN THE NUCLEAR SUPPLY CHAIN

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1. Introduction

The global nuclear industry is going through a period of significant growth and development with extensive activity around the world including:

- Large scale decommissioning programmes as plants developed in the 1950s & 60s reach the end of their operating life
- Nuclear New Build Programmes to support the ever increasing demand for electricity across the globe and to replace lost generating capacity resulting from plant closures combined with the need for energy security and reducing carbon emissions
- Requirements for waste management, storage and disposal
- Uranium mining & enrichment and fuel manufacture
- New technology development such as Small Modular Reactors (SMR)

This requires nuclear operators and Site Licence Companies (SLC) to have a highly skilled and competent work force. In countries with existing nuclear programmes there are already well-established programmes and systems in place to ensure this and new to nuclear countries are frequently working in collaboration with the experienced nuclear nations to develop the required competence and capability for the Operators.

However, a very significant part of the work in constructing, operating and decommissioning nuclear plants is carried out by the supply chain. It is therefore equally important that the supply chain can demonstrate it has a workforce with the competency and capability required to support the growing global nuclear programme. Additionally it should be noted that many of the supply chain companies supporting the nuclear programme do not just operate in one country but frequently operate on a global basis, making the demonstration of competence in a reliable and secure manner of ever increasing importance.

As the employer led body for skills for nuclear in the UK, the National Skills Academy for Nuclear (NSAN), set about responding to this need. Government co-investment was secured to support a small project team who, working with industry subject matter experts, have developed a common nuclear sector competency framework and a shared online competency management tool. Collaborative development of the framework is ongoing, supported by a considerable commitment of time and expertise from industry.

This paper outlines the approach taken by employers in the UK to address this challenge and explores how this could now be utilised more widely to support the global nuclear industry.

2. Does this already exists?

All UK Site Licence Companies (SLCs) and most major organisations within the nuclear sector have their own detailed competency frameworks. These internal frameworks, along with the systematic approach to training (SAT), rigorous assessment and recording processes are used to ensure a competent workforce. This comprehensive approach also enables SLCs to demonstrate compliance with a number of key Site Licence Conditions and the associated regulatory guidance and expectations set out in Safety Assessment Principles (SAP) and Technical Assessment Guides (TAGs).

Of particular relevance to this development, Licensees are responsible for ensuring, amongst other things, that its contractors are suitable for the work that they do.

A national nuclear sector competency framework cannot, and is not intended to, replace the existing SLCs defined competency requirements and processes. It does however provide a mechanism through which supply chain companies can ensure they align to the nuclear industry's agreed requirements and can also be used by new Site Licence Companies as the basis for their own systems.

SLCs have supported the development of the industry framework as they recognise the potential benefits to be derived at all levels of the industry.

3. Drivers for a common language of competency

Nationally and internationally there is a lot of focus on how to develop and ensure the competence of the nuclear workforce, including contractors. Examples of day-to-day issues include:

- Ensuring/demonstrating the currency of competence
- Defining, developing and maintaining the combination of competencies required within certain job roles e.g. a mix of technical, managerial, commercial, core safety and behavioural
- Ensuring the competence of contractors deployed alongside in-house teams
- Ensuring contractors and supply chain organisations understand the competence requirements of their customers
- Ensuring and demonstrating that individuals are able to combine relevant knowledge, skills, experience and behaviours in order to perform effectively in a given or changing context

The interface between SLCs and the supply chain is a particular focus and consideration of this work.

Supply chain understanding of nuclear, particularly SLCs requirements with regards to demonstrating staff and contractor competence, can be a barrier to entry. This can prevent otherwise excellent organisations from winning tenders or even failing to understand fully the requirements set out in specifications.

Being able to reference a common language of competence helps organisations to define and to interpret requirements consistently.

Organisations posting tenders:
a) benchmark their requirements against the industry agreed common framework
b) specify requirements referencing competency statements and levels within the common framework
Supply Chain companies responding to tenders:
a) accurately interpret requirements
b) develop their staff to meet the requirements, and
c) demonstrate their suitability using evidence aligned to appropriate competencies

Smaller supply chain companies and new entrants need clear definitions to understand and to evidence their competence in order to compete effectively.

For many roles within SLCs, competence requirements are articulated, at least in part, with reference to standard, organisation specific training inputs and assessments. This can make requirements difficult to understand for anyone on the outside.

With the right support, supply chain companies can bring transferable competence from other high hazard sectors without having to retrain and with the possibility of sharing good or innovative practice.

Agreement of the common nuclear sector competency framework, written to be organisation neutral, provides a significant step towards facilitating such transfer. With appropriate safeguards to ensure gaps and transition issues are addressed, the appointment of contractors with existing competence will drive efficiencies and help avoid issues of inappropriate selection and deployment.

4. So how common is common?

When you look across organisations, sectors and professions, competency frameworks do vary widely in the way they are written and used. Some describe what competence looks like at each level for each individual competency statement. Others embed expected levels of qualifications, the amount of post qualifying experience and specific training within the definitions, yet others aim to remain at a high level, specifying what the competent person is able to do; the output they are able to deliver. These sometimes seek to differentiate what a level 2 competent person will be able to deliver, vs someone performing at, say, level 3 or level 4.

In short, it can get very complex and very messy. There is no right or wrong approach, just approaches designed to meet particular needs.

5. Arriving at the 'right amount of detail'

To develop the Common Competency Framework we have brought together groups of subject matter experts for each discipline area, *e.g. Design Engineering – Mechanical; Nuclear Waste Management; Maintenance Engineering – EC&I.*

It is fair to say that each and every group initially struggled with the question 'how much detail is the right amount of detail'? Each workshop was attended by dedicated subject matter experts willing to share freely, some bringing their organisation's competency statements to the table, each with their own experience of a specific approach. It is testimony to the commitment of all involved that we were able to constructively discuss and dissect competency statements, to determine the parts that were widely applicable and transferable, identify aspects considered too organisation specific and highlight where statements were

The NSAN Approach

- Defines the widely applicable and transferable competencies
- Avoids granularity and organisation specific barriers to adoption
- Provides statements that are sufficiently meaningful that users can identify and combine competencies needed in job roles, significant 'tasks' and projects
- Enables competencies from different discipline areas to be combined in a single role profile , reflecting the complex nature of many roles in nuclear e.g. combining engineering, project management and technical nuclear safety competencies
- Enables a consistent approach to setting role specifications and competency assessment across organisations, departments/disciplines and across the supply chain

mandating particular training courses or evidence.

Through this process we have been able to reach agreement on a model that defines each competency using a single, high level statement. This allows users to assess and score competency using 5 generic level descriptors *(including Level 0 where a particular competency is deemed not applicable but may be identified as a future development target*).

Figure 1: A Common Competence Framework

6. Agreeing what to include

With the thorny issue of the right amount of detail addressed, within each discipline we have consistently witnessed remarkable levels of agreement between organisations, be they SLCs or supply chain, competitors or regulators, about the scope and level of the competency statements to be included in the framework. It is reassuring for those working in or seeking to enter the nuclear supply chain that there is a great deal of consistency across nuclear sector organisations when defining their requirements.

This provides great confidence in the transferability of the resulting Common Competency Framework.

While not an easy process, and always with a few 'outlier competencies' that are deemed essential by one or more participants but not so by the majority, the employers have been able to reach agreement around core requirements for each discipline.

Competency Sets Developed to Date

Core Nuclear Knowledge
Core Nuclear Behaviours
Design Engineering (Mechanical)
Design Engineering (EC&I)
Maintenance Engineering (Mechanical)
Maintenance Engineering (EC&I)
Technical Nuclear Safety
Project Management
Nuclear Waste Management
Nuclear Security
Quality
Civil & Structural Engineering
Nuclear Process Engineering
Procurement and Supply

Core Knowledge

- Industry knowledge
- Regulatory Knowledge
- Safety and Security

Core Behaviours

- Behavioural Safety and security
- Communication
- Developing Self and Others
- Focused Thinking
- Leads by example
- Teamwork
- Achieves Results

Disciplines

- Technical Nuclear Safety
- Design Engineering – Mechanical
- Design Engineering – E, C & I
- Maintenance Engineering - Mechanical
- Maintenance Engineering – Electrical
- Civil and Structural Engineering
- Nuclear Process Engineering
- Nuclear Waste Management
- Project Management
- Quality
- Nuclear Security
- Procurement and Supply

7. An inclusive development process

Subject Matter Experts nominated by their employers typically meet as a working group three times, supported by a technical author and a facilitator.

From a starting point of thrashing out issues of scope and level, including what not to include, the group gradually defines and refines a set of competency statements for their discipline, drawing on organisation and sector source materials as applicable.

At an advanced stage of development, usually between meetings two and three, wider sector consultation is undertaken using online surveys and email circulation. Once again we have seen a remarkable level of agreement regarding the focus and level of the drafts produced by the working groups.

Wider consultation is an important stage that does generate challenge and tends to highlight aspects that, on reflection, clearly need further work.

Amendments made in response to the feedback are scrutinised and tweaked as necessary by the working group, prior to submission to the nuclear sector's Standards Advisory Group[1] who approve their use in the sector.

Sector scrutiny is vital

If you do receive an invitation to participate in a working group or online consultation, please do take the time to contribute. The feedback is invaluable and it does get scrutinised at the level of individual comments.

8. So does one size truly fit all?

[1] Standards Advisory Group represents all UK SLCs at a senior level and determines the training standards to be adopted by the sector.

Unequivocally No. Setting out with the aim to develop a common language of competency has not, and cannot produce a single framework that accurately captures the myriad requirements across all organisations in the sector. Agreeing a framework of competencies required in many organisations and roles provides a sound basis and benchmark for defining and demonstrating competence. The Common Framework was never intended to provide a complete, comprehensive framework for most organisations. Commercial, competitive or technical differentiators mean that companies need the flexibility to define and apply the specific competencies required in their business.

The Project Team recognised this at an early stage. They determined that a tool which allows companies to combine nationally agreed competencies with those specific to their business was required. This resulted in parallel development of the new NS^{4}P Competency Management System (Skills Assured in the international market).

9. A flexible solution

Designed for flexibility, the Skills Assured approach enables organisations to build their own competency framework around the national 'master'. An organisation selects all applicable competency sets from the National NSAN Master Framework which provides each organisation with a consistent foundation that supports a common language of competency. They can then add their own specific competencies. The resulting organisation specific framework can then be applied flexibly, combining 'master' and 'organisation specific' competencies to specify requirements for roles and even for particular projects or tasks.

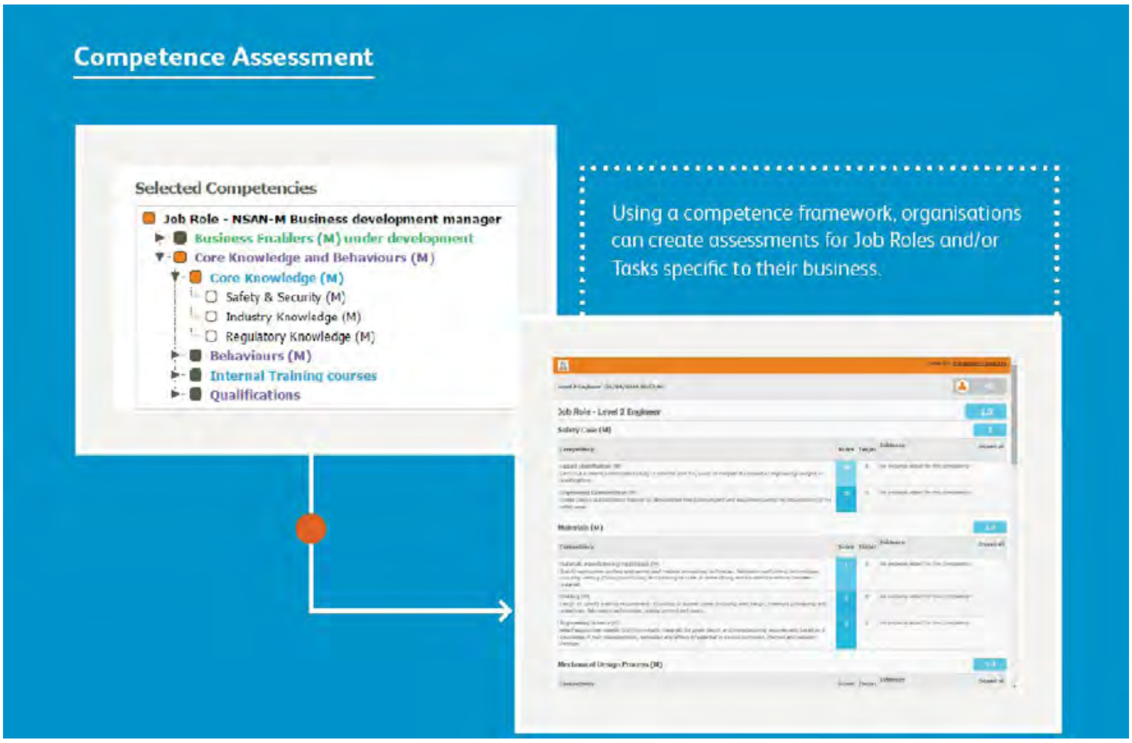
Embedding the agreed competency statements enables organisations to demonstrate competence using a common language, for example when responding to tenders; adding organisation specific competencies ensures that a single organisational framework can be applied across the business. Being able to tailor and update an organisation framework enables it to meet the business' evolving needs. For example, should an organisation decide to expand into a new area of work, they can pull down the current nationally agreed competencies for this area and incorporate them into their existing framework. The Skills Assured system can then be used to manage development and capture evidence of the required competencies in advance of tendering.

NS^{4}P in practice

The Gatekeeper Role - Tenders and Procurement

With the SLC/Supply chain interface in-mind, Gate-Keeper functionality allows supply chain companies to provide evidence of the competence of their proposed team. Access can be provided to a nominated 'Gatekeeper', on a time limited basis, to view evidence of the team's competence recorded against the Common Competency Framework. The bidding organisation controls which information is visible to protect confidentiality and safeguard against potential 'poaching' of staff.

Figure 2 below shows a screen shot of a Competency Assessment



10. More than a Competency Management Tool

Skills Assured licences are available to be purchased in various ways, contact enquiries@nsan.co.uk for detail.

Recent additions include:

- Gap analysis and training planning
- Training Directory – linked to competencies, identifying and accessing support from an approved network of High Quality Training Providers to address identified gaps
- Resource Explorer – allowing search and drill down across the organisation, helping to build project teams with specific combinations of skills and experience
- Report generator – tailoring reporting to locality and organisation needs
- Gatekeeper functionality - supporting the tender process
- Evidence repository and showcase - proving competence at individual, team and organisation levels

While it started life as a Passport tool, the enthusiastic adoption by the sector of the updated Skills Assured Competency Management System highlights that this development is helping to address a challenging and complex issue for many organisations. The functionality and flexibility of the system will continue to develop as we listen to and respond to the needs of our members.

11. Closing the loop – planning and supporting CPD and professional recognition

Most, if not all, Professional Bodies have Continuing Professional Development (CPD) policies and processes. This can include submission of annual returns by members. It is important to note that CPD is, and remains, the responsibility of the individual and usually forms part of their formal commitment as a professional within their given field. It is also the case that much CPD takes place through informal learning as a natural part of working life. Such informal learning can be supplemented by specific training or development activities.

Skills Assured supporting CPD

- Utilising the tool to undertake competency assessment against national and local competencies – including development planning
- Training directory help to identify and access targeted CPD
- An individual Evidence book with export functionality, recording evidence of CPD
- Align individual and organisational requirements for mutual benefit
- An opportunity to formalise and integrate annual CPD returns, providing a win-win for the individual and their employer

The nature of the CPD an individual chooses to undertake will also vary depending on their circumstances and aims, such as increasing competence in their current role or, perhaps, working towards a longer term goal. Clearly this can and will change over time.

CPD is intended to benefit the individual and will also usually benefit their employers, their customers and society as a whole.

The Common Competency Framework provides an excellent tool that individual Nuclear Professionals can use to reflect on current skills and competence and to plan their professional development.

12. Conclusion

Are we as an industry consistently and adequately managing competency?

One perfectly valid answer is *'we always have'.* And I agree. Through fit for purpose competency frameworks many organisations within the UK's nuclear industry have a superb record in managing the competence of their workforce.

The confidence to which I refer, and that we are collectively seeking to build, is in the competence of the UK Supply Chain to understand and deliver to the sector's exacting standards.

The Common Competency Framework and fit for purpose competency management tool, the NS^{4}P, go a long way to supporting suppliers to respond to the challenges of the UKs Nuclear Programme.

The level of industry support and subsequent adoption of the Framework and NS^{4}P, signifies that we have put in place two vital building blocks to Creating Confidence through Competency and we are now keen to share this learning and expertise with our international colleagues via the Skills Assured system.

More information can be accessed at www.ns4p.co.uk and www.skillsassured.global

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Human Resources Trends and Analysis for the Nuclear Energy Sector. Post-Fukushima Report.

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Abstract

The European Union has been building up its nuclear knowledge base since the 90s. The impact of the Fukushima accident has affected the entire nuclear sector, turning public opinion perspective against nuclear energy exploitation, and leading some member states to a gradual phase out. Stakeholders changed their strategies, recruiting less nuclear experts, adapting their decision to the new energy scenario. Some countries have adopted measures to radically redesign their nuclear and energy policies.

Since 2010 the European Human Resources Observatory for the Nuclear energy sector has been providing qualified data on human resources needs in the nuclear field within the European Union and high-level expert recommendations on EU-wide nuclear Education and Training action, thus promoting lifelong learning and cross border mobility.

The paper will analyse the situation regarding the trends in human resources and education in the European nuclear energy sector, pointing out the effects of the Fukushima accident in Europe.

The European Human Resources Observatory for the Nuclear Energy Sector (EHRO-N) was established in 2009 to permanently observe and monitor the nuclear human resources in the European Union. It is managed by the European Commission's Joint Research Centre Institute for Energy and Transport, located in Petten, the Netherlands. Its activities serve the European Commission, and member states' needs and priorities for the sector.

The Observatory monitors the evolution of the nuclear energy sector, identifying trends and patterns for intra- and extra- sectorial mobility, measures the distance between current levels and future requirements of knowledge, skills and competences, and evaluates the possible scarcity of resources and bottlenecks in knowledge sharing and management.

Since its establishment, EHRO-N has produced periodic trend analysis for the nuclear Human Resources situation and analysed the quality of European nuclear Education and Training infrastructure, benchmarking the data with Asian and North American experiences. Two main surveys and several analyses were conducted since EHRO-N establishment. It emerged that the interest in nuclear construction began to fade slowly before the Fukushima accident, as an increase of attention was given to the development of renewable energy sources. After the accident, an expanding negative perception of nuclear energy production and the economic crisis brought a drastic reduction in personnel recruitment expectations.

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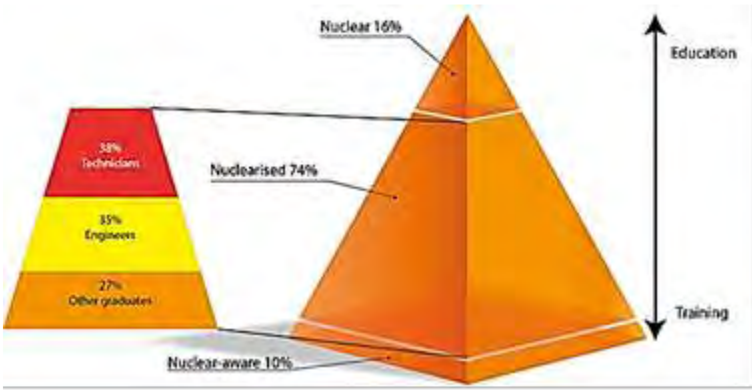

Figure 1 Pyramid of Skills (source: EHRO-N)

To analyse the composition of nuclear workforce EHRO-N developed the "pyramid of skills", in which nuclear experts represent the 16% of the total workforce, while "Nuclearized" experts are the 74%. The analysis pointed out a difference of ±30% between demand and supply in the area of human resources with nuclear studies, mainly among the "nuclearized" staff. In fact, taking into account the large scale retirements in the near future, the supply of nuclear engineering students in nuclear energy-related subject covers only ±70% of the demand for nuclear experts by the EU nuclear energy sector.

Among other data collected, the age span analysis showed that the most numerous group resulted to be "45-55". Moreover, the age group "up-to-45" is smaller than the age group "45-and-above", probably indicating a lack in recruitment of younger experts in the last years.

During these years, EHRO-N has become an inspirational model not only for the IAEA Regional Networks (LANENT, ANENT, AFRA-NEST), but also for a vast number of interested stakeholders, inspiring training programs for experts' mobility in many European countries. The methodology has also inspired the South Korean Nuclear Education and Training Information Centre (KONIKOF – NETI).

The present EHRO-N approach seeks to avoid gaps and duplication by establishing a clear relation with other existing working groups on nuclear education, in order to monitor the situation and verify existing workforce models and modelled scenarios to be compared with real scenarios. The analysis showed that, compared to historical data for the nuclear capacity being installed at the same time in Europe, the expected future capacity needed is significantly lower than in the late 70s. However, even if the peak force for securing the nuclear energy share is lower, a higher demand in the first 10-15 years will be necessary. This is due to the fact that not only additional nuclear power plants need to be built to keep up with the growing nuclear energy demand, but also to replace the current nuclear reactor park.

ACRONYMS

EHRO-N: European Human Resources Observatory for the Nuclear Energy Sector
IAEA: International Atomic Energy Agency
KB-QS: Knowledge Based Qualification System
CB-QS: Competence Based Qualification System
KSC/A: Knowledge, Skills, Competence/Attitude

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EXPERT MANAGEMENT AT AREVA IN GERMANY

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ABSTRACT

Maintaining the expertise in technical domains being critical for a company's businesses and to ensure the commitment of the staff even in economically challenging times is one of the main efforts of each technological company. Depending on the evolution of technology and associated business, it is also crucial to build expertise in technical domains in which skilled work force is not available on the labour market. Therefore it is indispensable for any technological company to identify, recognize and promote employees who carry exceptional scientific and technical skills as a prerequisite for technical innovation and in order to be able to solve complex product related technical issues. Experts are also an indispensable for the management to make good technological choices that are in line with product strategies

This article reports about AREVA's practices to identify, qualify and certify experts, to make them visible within the company by an expert database and other measures, and to further develop the expert's technical and personal skills. It is also reported on how the required population of experts by individual technical domain is derived from the company strategy, i.e. how the College of Experts is required to evolve depending on external impacts, internal road-maps, as well as know-how in- and outsourcing. The success of the AREVA Expert model is steadily reviewed by feed-back with project managers and line mangers and via surveys on the company's innovation culture. It is to be pointed out that efficient expertise management requires a joint effort between Human Resources, Research & Development, and the talent identification and promotion in the operating units.

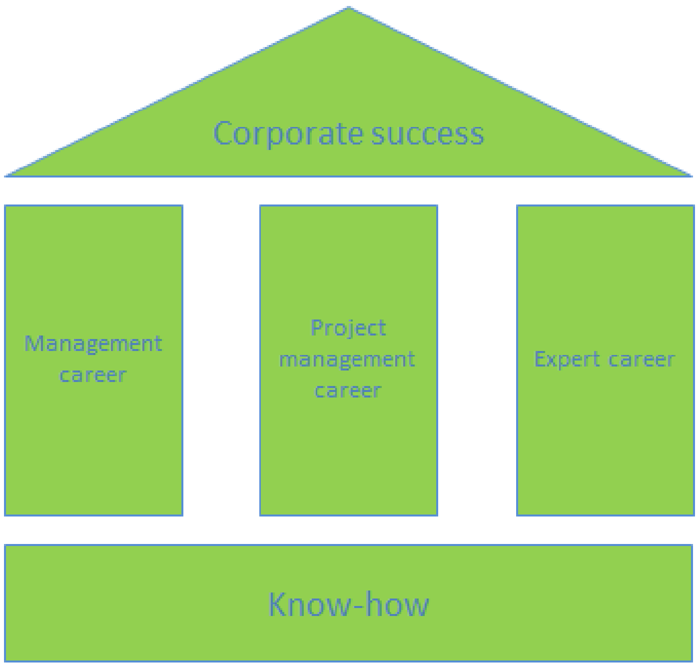
1. From the nuclear phase-out in Germany to a new corporate strategy

The nuclear phase-out in Germany is obviously fundamentally impacting the domestic nuclear industry. AREVA, a nuclear engineering company with business activities focusing on nuclear plant construction and services as well as nuclear fuel supplies, is thus being faced with the challenge that the German market will gradually phase out in the years ahead. AREVA, in particular AREVA GmbH in Germany, has therefore adapted its corporate strategy to the changed boundary conditions and is focussing above all on the export of its internationally renowned nuclear competencies and services. In addition to exports to countries with a stable or aspiring nuclear market, these nuclear engineering competencies are also available for continued safe operation of the German plants and for gradual decommissioning of the nuclear power plants in Germany. AREVA is also pushing ahead with the marketing of existing nuclear technologies in other industries outside of the nuclear sector. For example, AREVA is supplying test and inspection facilities to branches of industry with similarly high safety standards, such as the air and space industry, and the rail transportation sector. Furthermore, the company is developing new technologies such as offshore wind farms and energy storage systems. In all of these activities extensive, in part unique technical expertise and experience are playing a decisive role. Like any other high-tech company, AREVA also has to place special emphasis on the retention and further development of its know-how. This is the more challenging as AREVA has utilized natural fluctuation in the wake of the nuclear phase-out resolution to adapt its workforces to the changed market conditions.

Specialist know-how from various disciplines is combined particularly in the field of nuclear engineering. For example, engineers work together with materials scientists, architects and specialists from many other disciplines in the construction of nuclear power plants. This clearly demonstrates that business is highly dependent upon pertinent know-how and specific competencies. It is therefore imperative to identify and systematically promote staff members who possess particular scientific and technical skills. To this end AREVA utilizes a comprehensive, company-wide expert management concept.

The standard for HR development in many companies is a structured management career. Particularly in engineering companies also have a parallel project management career. By contrast, in many companies little attention is still paid to a systematically organized expert management. AREVA made the decision at an early point in time to establish the expert career as a career of equal standing to one in management.

The expert career as a career of equal standing in HR development:



2. Expert know-how clustered in 14 domains

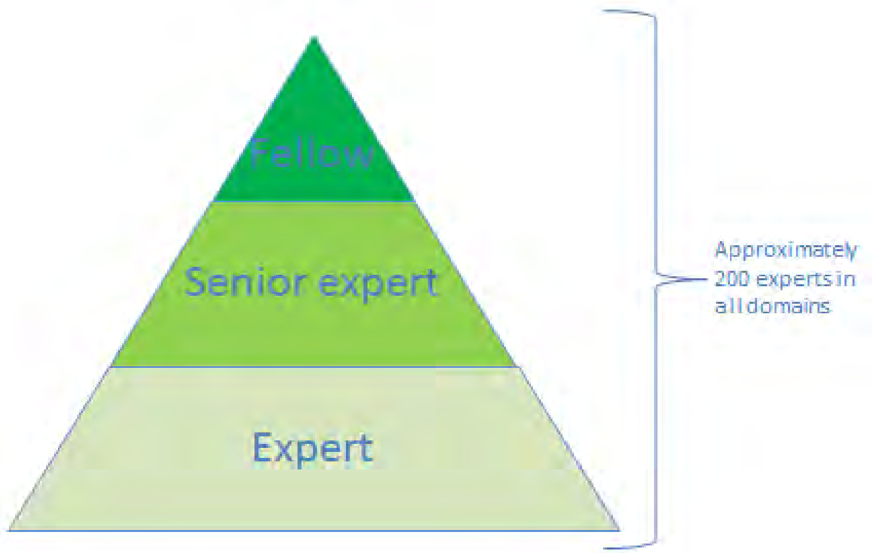
There are currently around 200 experts among the workforce of approximately 4100 at the German regional company AREVA GmbH. Company-wide there are around 1000 experts. These are assigned to 14 domains with several sub-domains. The scientific and technical domains, for example, include the domain for manufacturing techniques and processes for large components used in nuclear power plant construction. Another domain focuses on IT and communications competencies, and extends to cyber security. On the intranet, every AREVA employee can access a company-wide overview, and can thus find and contact the cognizant specialist to meet the needs of his/her customers.

The expert career is open to every AREVA employee with a scientific and technical background. The ratio between the number of experts and overall workforce should, however, remain approximately constant over the long term. HR planning software is utilized for expert requirements planning. It acts as a central database for all jobs and professions within the company and can indicate both the status quo and the planned development over the years ahead. It is thus possible to show employees grouped by their specific fields of expertise, and to use this as the basis for the initiation of development measures.

After around five years of service within the company, an application can be filed for a career as an expert. These five years are considered the minimum period required to accumulate sufficient know-how relating to company- and branch-specific challenges and prove one's competencies. Experts are appointed every two years in a multi-tier, selective process. Candidates submit a written application with their personal details, current field of activity and contributions made in their specific field. The responsible manager, HR development and research & development (R&D) function within the appropriate business unit drive this process forward. Candidates attend several interviews, in which they can substantiate their application. In addition, current experts have the opportunity to recommend new candidates. Entry to AREVA's expert management takes place at Level 1 in a three-tier system.

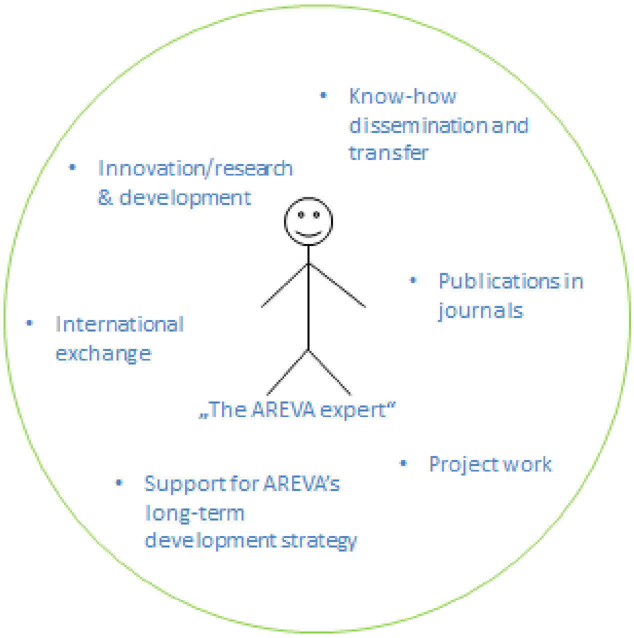
For appointments and promotion to the next expert level there are committees in which R&D managers, line managers, other experts and HR development assess potential candidates and make decisions on appointments. Depending on the level in question, candidates are assigned different tasks. Among other things, fellows at the highest level advise the managing board on issues including fundamental decisions on investments. Senior experts are active in the business units, where they advise decision-makers, for example on issues relating to major projects. Experts at the first level are often involved in concrete projects, where they advise project managers. In addition, experts participate in coordination of the management of internal R&D processes.

AREVA's expert levels:



Furthermore, all experts are expected to participate in international forums and conferences in their specific field and to regularly publish articles in pertinent journals. They drive forward international development partnerships on a scientific and technical basis, not only with universities and research centres but also with partner companies and customers. In particular, AREVA's customers benefit from the latest technical standards through the networking of each expert field. A further special feature is a freely assignable work time. Experts have the opportunity to dedicate part of their work time to the development of their own ideas and visions. In addition, within the framework of its General Expert Program (GEP) the company also enables experts to further develop their soft skills.

Task areas of an AREVA expert:



3. Expert management supports the transformation process

The nuclear phase-out in Germany has significantly changed the dynamics of AREVA's market environment. Expert management makes a major contribution toward adapting to the changed market conditions within and outside of Germany under the terms of the adopted corporate strategy. This includes retention of the existing comprehensive competencies in the nuclear sector and further development of these competencies to remain an international leader. An example of this is the spent fuel pool at Gösgen nuclear power plant in Switzerland, which features an innovative passive cooling system.

Nuclear competencies can, however, also be applied in other areas. For example, advanced ultrasonic testing facilities deployed in nuclear applications are in the meantime being used for quality control in the production of aircraft and in the field of rail transportation systems. It is also necessary to develop new fields of business, for example energy storage systems within the framework of the energy system transformation in Germany. The company has developed an LOHC (liquid organic hydrogen carrier) technology, which enables longer-term, zero-loss hydrogen storage. There, expert management is building up new competence for these highly promising fields of business.

This further development of competencies within the framework of expert management has already produced first concrete projects. For example, AREVA is a partner in the Smart Grid Solar project in Bavaria, which is investigating the impact of different storage technologies on the power in-feed into the regional grid.

Generation Y and Z meet Generation III

SECURING OUR NEXT GENERATION OF NUCLEAR EXPERTS THANKS TO ENTHUSIASM, PASSION AND KNOWLEDGE SHARING

OLIVIER GILMONT

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ABSTRACT

In the context of wide-ranging renewal of the Tractebel Engineering (TE) Nuclear teams, due among others to the workforce ageing, the company – which provides technical expertise in various specific domains for the Belgian Nuclear Power Plants since more than 40 years – has set up an innovative and attractive knowledge management program explicitly aimed at training the newcomers, improving collaboration between colleagues and capitalizing on expertise.

The skills transfer is carried out per technical domain, from several experts to several juniors, in order to dispatch the knowledge. This process emerged from unsuccessful experiences consisting in setting all expectations on only one newly formed expert.

To sustainably secure the expertise inside TE Nuclear, a dynamic “learning by teaching” method is implemented: all along the process, various theoretical and practical tools are created by the juniors themselves, which are also aimed at training upcoming newcomers. Emphasis is also put on the transmission of the passion for the job, to motivate and retain the young generation.

This has been successful in technical domains such as valves, actuators, material ageing and in-service inspections expertise's. Following the same strategy, the pumps expertise program will start in 2016, certainly followed by more to come.

1. Introduction

Based on more than 40 years expertise, Tractebel intends to remain a strong actor in the nuclear industry.

The predicted decrease of nuclear skilled personnel and its wide-range renewal did put the light on the skills shortage of this industry to support operation, maintenance, life extension and decommissioning of the current plants and possibly to build new ones at the same time. In this context, skills management became a burning issue for every actor of the industry: vendors, utilities and nuclear regulators.

In addition, Tractebel experts have high level expertises in very secific nuclear domains, which makes the knowledge maintenance critical; such profiles are not easilly found on the employment market. Besides, career expectations have changed between generations; while a linear career was expected by the older generation, the new Y and III generations are more inclined to mobility.

Since about 10 years now, skills management tools have been developed in order to face the challenge:

- Firstly, the tools aim at detecting the skills that will soon be on shortage and that are required to continue performing Tractebel's role of Nuclear expert leader.
- Secondly, specific programs are set up, per section, to streamline the knowledge transfer between senior experts and juniors/newcomers.

This paper adresses the solutions that Tractebel has set up to meet the second point, as the first point has been developed in a previous NESTet paper[1].

The 2010 age pyramid of the Nuclear Mechanical Equipment team (composed of several core experts for Nuclear mechanical equipment) is illustrated here under, showing that: a third of the employees are young newcomers under 30 years old, while almost half of the employees are aged experts, close to retirement. Very few middle aged employees are present.

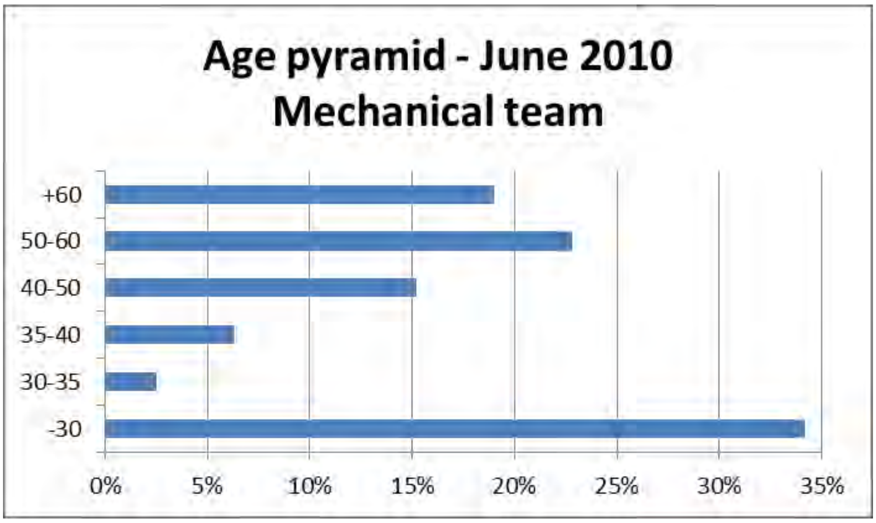

Fig 1: age distribution of Tractebel mechanical team in 2010

[1] Nestet 2011 - Securing our nuclear skills for the future, Argani, N. (1); Ben Soussan, S. (1); Vanhoenacker, L. (1); Hindryckx, B. (2) / 1 - Tractebel Engineering, Belgium / 2 - Electrabel, Belgium

Through this paper, it will be analysed how Tractebel developed an attractive knowledge management program, explicitly aimed at training newcomers, improving collaboration between younger and older colleagues, capitalizing on expertise, while developping critical thinking and creativity. This is what Tractebel calls the "skills maintenance program".

2. Skills maintenance program – strategy

2.1 Initial strategy – weaknesses

The initial strategy set up to implement the skills transfer consisted in assigning one junior to work closely with a senior to learn from, in order to gain its expertise. This strategy worked pretty well at first as the one-to-one collaboration was very efficient and created a strong connection between senior and junior. However, it started to collapse when the newly formed juniors decided to quit the company, making the time and effort spent in the skills transfer program fruitless and forced to re-start the process, from scratch. Thereby, it was decided to adopt an alternative approach.

2.2 Improved strategy

The improved strategy currently applied and implemented several years ago consists in creating groups of juniors per technical domain, expected to learn from one or several experts and from each other. Each group is composed of a junior leader asked to drive the skills maintenance program. Other juniors have to involve themselves to increase their technical knowledge in the domain by participating and performing tasks delegated by the leader. Newcomers are intended to join one or several groups to intensify and secure the program. To ensure success, following key aspects are implemented:

- Selection of appriopriate profiles: juniors showing a high interest in deepening technical knowledge, expected to perform a long career in the technical field.
- Encourage the juniors to be actors of the knowledge/skills transfer: it is expected from them to be proactive towards the experts, to initiate contact and to be innovative in order to create tools/methods to improve the process. Solutions are not brought immediately by seniors in view of inducing a real group reflection. The idea of the program is to grant juniors a large autonomy and latitude (however supervised by managers and experts) to stimulate their creativity and to make them feel like the ambassadors of the program;
- Stimulate the interest/passion of the juniors by making the program attractive with practical, attractive & various study subjects.
- Promote the teamwork spirit by working in groups where possible. Tight collaboration, good relations between colleagues and extending personal professional network are considered as keys of success. Moreover, groupwork pormotes a healty learning emulation;
- Implement a "learning by teaching" method, as much as possible;
- Sensitize seniors to be available for juniors at any time;
- Mitigate the workload of seniors by delegating tasks to juniors. As a matter of fact, the number of senior experts tends to decrease, but the workload intensify with projects like the life extension of Nuclear Power Plants or with regulations getting more and more severe. Juniors will learn by being involved in various projects, and seniors could dedicate more time to train the younger generation;
- Ensure that the knowledge transfer process is continuous and sustainable.

3. Skills maintenance program – implementation structure

3.1 Expertise domain distribution

To organise the skills maintenance, core skills for which a knowledge transfer is needed are identified and divided in technical expertise domains. For each domain, a senior expert is designated as *reference person (coach)*.

To keep the program attractive and varied, a junior may choose between several expertise domains for which he feels some interest. However, experience showed that limiting the focus on few domains is a good solution, providing variety while not scattering energy. While experience is gained by the junior, he turns step by step closer to the expert position, allowing him to diversify expertise subjects and leaving space for another junior of the group.

As an example, the organisation of the valves skills program is as follows in the mechanical supply section (counting a total of 20 employees):

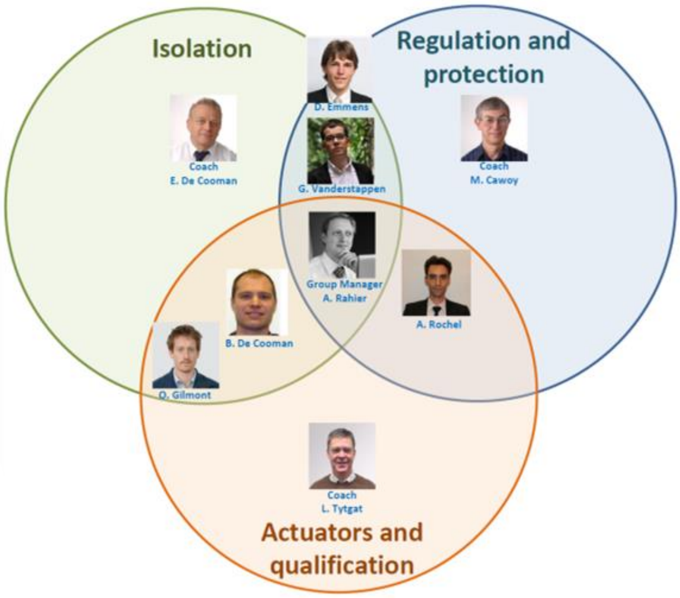

Fig 2: Organisation of the valves skills program in the mechanical supply section

- 3 seniors, coaching the expertise domains;
- 5 juniors, each one taking part in two expertise domains. In addition, one leader is designated per expertise domain to organise and stimulate knowledge transfer;
- 1 group manager, checking that the program runs efficiently: guarantee sufficient resources in all expertise domains; release enough budget; select appropriate junior profiles; define personal and group training objectives; ensure attractiveness of the program.

3.2 Tools

In order to make the development of a knowledge maintenance program possible, following tools are put at the disposal of the expertise teams:

- **A specific training cost centre**: this allows the participants to be fully dedicated to the trainings, giving them the possibility to prepare themselves beforehand (e.g. by reading documents covering the subject to be discussed) and to write "educational notes", summarising the learning process and the key points.
- **A "learning by teaching" method:** within the company, juniors receive the responsibility of training their junior colleagues through so-called "study cases". Through this process, learning is also made more efficient for junior trainers, as they have to deepen the subjects before being able to teach. On the other hand, the junior trainer "speaks the same language" as other juniors, improving the knowledge transfer. Outside the company, juniors are involved in supporting seniors to give specific expertise trainings.
- **A dedicated role for the expert coaches:** they are requested to remain available for all questions that the junior trainer could have when preparing a study case, in order to ensure an efficient presentation. Afterwards, their role is to supervise the study case, answering some questions that arise and orienting debates. After the study case, their last role will be to supervise the reporting, ensuring its exactness and relevance, as the report is of essence for the continuity of the process. In addition, seniors are also asked to share their professional network with the juniors.
- **An efficient documentation support:** this allows juniors to easily access technical information as needed, anticipating the nearby retirement of remaining experts involved since the construction and start-up of the Belgian nuclear power plants. Technical notes are archived on an internal e-portal and accessible from every company's computer. As mentioned here above, after technical trainings, specific notes are written to summarise learnings and to verify with the coaches the good comprehension of the subject. As much as possible, notes are written to be easily understandable: diagrams, drawings and schemas explaining each step of the reflection followed by the group during the study case. In addition, a folder is created on an internal server, where all juniors have access and where diversified technical information are stored, such as pictures, short technical movies, past exhibitions information etc.
- **Internal company's communication:** a dedicated "Skills maintenance" intranet webpage gives visibility to all actions and possibility to share them with other sections of the enterprise.
- **External company's communication:** juniors are encouraged to draft technical articles for international publications and to present papers on their expertise field at international conferences.
- **Involvement in technical projects:** the juniors participating to the program are actively involved in expert technical projects, as for example by drafting or verifying technical notes concerning their expertise domain, increasing their field experience by following activities on site (inspection operations, mechanical equipment repair/replacement, etc.) and leading to practical implementation of "theoretical concepts" learned during study cases, in small groups. A good way to develop the competences of juniors is to lead them out of their comfort zone by confronting them to difficult challenges, such as leading resolution of critical technical issues, managing alone discussions with clients, contractors and safety authorities, etc.

- Tractebel also participates to a yearly specific training program for newcomers, the “Nuclear Trainee Program”, created 10 years ago by the ENGIE group, that provides over a year diverse practical and theoretical courses to give the fundamentals of nuclear technology while helping developing a dynamic professional network within the group. This program is of essence to speed up the experts skills transfer.
- The knowledge maintenance program is not frozen. Participants are always welcome to propose evolutions of methods or tools, or to propose visits to manufacturers or conferences that would improve the knowledge comprehension. This is, again, a way to actively include participants in the learning process, which is a key to dynamism and enthusiasm enhancement.
- **Technology watch:** participation to international conferences and close collaboration with suppliers to be aware of new products available on the market.
- **Extension of working field outside the nuclear industry:** diversity brought by activities outside the nuclear industry, performed to experience other high technologies/challenges in line with the skills maintenance scope.
- **Close collaboration with the Customer:** juniors are rapidly placed in the front line when communicating with the Customer, developing their soft skills. This approach also demonstrates to the Customer that continuity of the expertise skills is ensured.

4. Conclusions

The graph here under shows the evolution of the age distribution over 5 years at Tractebel.

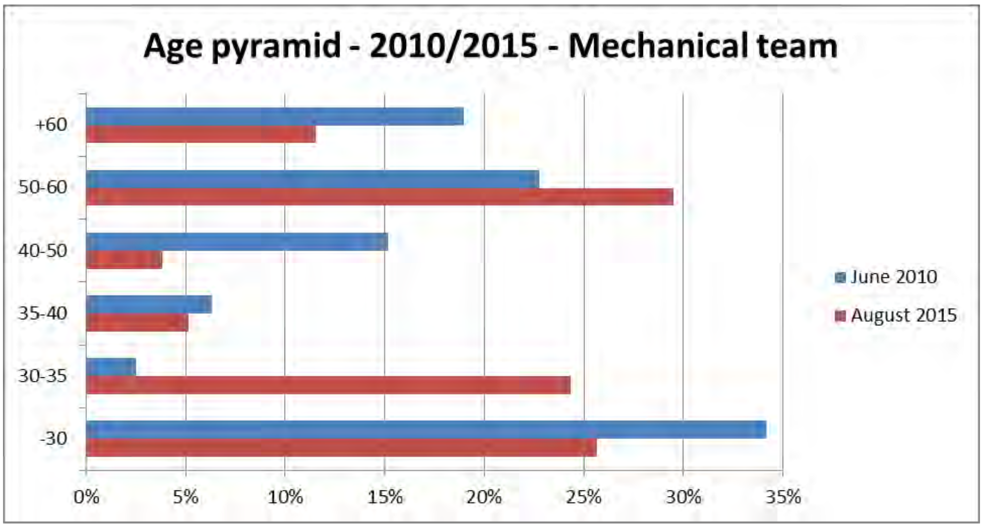

Fig 3: age distribution of Tractebel mechanical team in 2010 and 2015

As said in the introduction, a third of the employees in 2010 are young newcomers under 30 years old, while almost half of the employees are aged experts, close to retirement. Very few middle aged employees are present. In 2015, the 30-35 age range has significantly increased, as a large part of the juniors of 2010 stayed in the company and gained 5 years of expertise thanks to the skills maintenance program. The program was reinforced by a high representation of newcomers (-30 y) who can now learn from the older experts but also from the previously trained juniors. This gives great confidence for the future as a large number of young employees (-35y) can take over the experts work, as the skills maintenance program is now organised by groups and not by a one-to-one transfer. The sustainability of the program is thereby guaranteed.

As a result, concerns related to career mobility expectations of the generations Y and III, previously impacting the company, are now mitigated.

The strategy of the skills transfer program has shown success as its main objectives are met: juniors are more and more autonomous and their competences reach the expected level. Besides, interest and good collaboration are apparent and the system continuously keeps improving.

As the program has been proven, the structure and the methods can easily be replicated in other technical domains where expertise preservation would become critical.

Broadening of programs to adapt to emerging needs

Cybersecurity: Moving Forward With Online Nuclear Education and Training

Dr. Jane LeClair

Cybersecurity is one of the greatest challenges facing our technologically based world. As technology has advanced we have become increasingly reliant on it for a myriad of tasks. The connectivity of technology is however a double edged sword. While it has brought us convenience in allowing us to streamline our tasks, it has also opened up many windows of vulnerability that those with malicious intent are determined to take advantage of.

Hackers are relentless in their efforts to breach critical infrastructure sectors, especially those related to the energy sector. Presidential Policy Directive/PPD-21 identified 16 sectors that were deemed as essential to the ongoing viability of the nation, it's business and defense. Those sectors have been identified as: the Chemical Sector, Commercial Facilities Sector, Communications Sector, Critical Manufacturing Sector, Dams Sector, Defense Industrial Base Sector, Emergency Services Sector, Energy Sector, Financial Services Sector, Food and Agriculture Sector, Government Facilities Sector, Healthcare and Public Health Sector, Information Technology Sector, Nuclear Reactors, Materials, and Waste Sector, Transportation Systems Sector, and the Water and Wastewater Systems Sector.

Defending our digital systems, especially those related to the energy sector through effective cybersecurity, has become of prime importance. Time and again hackers attack our digital networks trying to gain control of our SCADA systems and do damage, or emplace a piece of malware that will trigger at some future date. These increasing threats need to be addressed with effective cybersecurity training that is aimed at all levels of the energy sector.

Admiral Mike Rogers, NSA Director and Commander of U.S. Cyber Command has said that "You must train like you fight, and you don't wait until the first day of combat to plan your fight". With that in mind, the federal government has allocated increasing amounts of funding for cyber security and training within the government, and advancing initiatives within the private sector. Effective training and education is therefore vitally important in combating cyber security issues.

For many years the traditional classroom was the only standard method for imparting knowledge to learners. However, with so many constraints on time and with costs rising, many organizations are turning to a different mode of education. One of the fastest growing and efficient methods of imparting knowledge about cybersecurity is through online learning. For many years The National Cybersecurity Institute (NCI) and Excelsior College recognized the importance of cybersecurity training and began searching for effective ways to offer numerous learning opportunities. One of the paths to training and education is through what is known as Massive Open Online Courses (MOOCs - rhymes with dukes). Originating in 2008, respectable learning organizations offer these online courses worldwide via the Internet and allow for an unlimited number of participants. These increasingly popular courses offered prerecorded lectures, videos, structured readings from a text and interaction with online professors. Noting their popularity, Baggaley, (2013) reports that "….traditional universities across North America, Australia, Asia, and Europe are adopting the massive open online course." Similarly, Vardi, (2012) wrote that "…the current wave started in the fall of 2011 when about 450,000 students signed up for three computer-science courses offered by Stanford University." Another researcher, De Coutere, (2014) noted that "More than 10 million people have taken a MOOC."

Excelsior College, in collaboration with NCI, recently offered a free MOOC entitled 'An

Introduction to Cybersecurity' that was well attended by over 10,000 participants from around the world who were seeking a basic knowledge on the intricate workings of cybersecurity. The course introduced learners to the concepts of cyber security, including, but not limited to an overview of the evolving and dynamic field of cyber security. This online MOOC was such a success that it has been repeated on a revolving basis as appropriate numbers of learners register for the course.

Excelsior College also applied for and received a grant from the American Society for Engineering Education (ASEE) to develop an online course that would provide free online cyber security training to engineering technology professionals. In addition, Excelsior College is developing a cybersecurity concentration in the nuclear engineering technology program which currently has over 1,500 online students. The college is also offering a new online course, entitled 'Cybersecurity for Utilities' through the college's 'Center for Professional Development'. According to the college website, "If you seek the knowledge necessary to enter a new field or advance in your current position, Excelsior's Cybersecurity for Utilities is a flexible non-credit certificate program that can help you succeed without disrupting your work and family responsibilities". The topics covered by the course include:

History of cybersecurity and emerging trends
Computer and application security
Personal, physical, and mobile/wireless security
Internet (vulnerability)
Security awareness education
Compliance, laws, standards, and ethics
Security professionals and certifications
Risk assessment and management

Utilities fundamentals

Cybersecurity threat vectors

Cybersecurity laws, regulations, and the cybersecurity workforce

Defense in depth and best practices

Upon completion of the course the learner has earned a certificate attesting to their acquired knowledge. The course will also cover emerging trends in cybersecurity as well as topics ranging from Internet vulnerabilities, awareness training and risk assessment to application security, best practices, and wireless/mobile security. Excelsior College also offers a variety of undergraduate and graduate degrees in cybersecurity, all taken online with the flexibility that many learners seek today.

By all estimates cyber attacks on the digital systems of our critical infrastructure will continue to evolve in their sophistication and only increase in intensity in the near future. According to Symantec, "In 2015, we saw a record-setting total of nine mega-breaches, and the reported number of exposed identities jumped to 429 million. But this number hides a bigger story. In 2015, more companies chose not to reveal the full extent of their data breaches. A conservative estimate of unreported breaches pushes the number of records lost to more than half a billion". MacSweeney (2016) notes "The frequency and intensity of cyber attacks on financial institutions has increased exponentially in the past 12 months. In addition, the financial losses from cyber attacks have reached into the billions". Cybersecurity specialist Mcafee suggest that

> "...the likely annual cost to the global economy from cybercrime is more than $400 billion. A conservative estimate would be $375 billion in losses, while the maximum could be as much as $575 billion. Even the smallest of these figures is more than the

national income of most countries and governments and companies underestimate how much risk they face from cybercrime and how quickly this risk can grow."

Clearly there is a need for ongoing training and education to help prevent those with malicious intent from breaching our digital systems.

Training in our current technologically evolving society comes in many forms from traditional brick and mortar schools to online courses and various hybrids. Learning institutions are constantly seeking new ways to bring the most effective learning to those who have a need for further education and training. In today's society that is coming more and more in the form of online learning which provides flexibility, effectiveness and convenience to learners. Having the proper education and training to combat those with malicious intent can help to forestall their efforts and NCI/Excelsior College is proud to offer that training and learner assistance.

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INPLEMENTATION OF KNOWLEDGE MANAGEMENT TOOLS IN UNIVERSITIES

DEMYANUK D.G., PERMINOVA M.V.

ABSTRACT

Nowadays one of the most important problems of atomic industry is nuclear knowledge preservation. Nuclear knowledge is defined by the International Atomic Energy Agency (IAEA) as knowledge specific or relevant to nuclear related activities. For this reason nuclear knowledge stakeholder such as government, international organizations and industry start to develop knowledge management systems.

An additional point is that one of the Nuclear Knowledge stakeholders is academic institution also. Using nuclear knowledge management techniques and technologies in higher education is as vital as it is in the industry. IAEA already has vigorous activity in developing of nuclear knowledge management for R&D project managers and other workers from nuclear R&D organization. This activity is reflected in IAEA publication “Knowledge Management for Nuclear Research and Development Organizations”. It highlights such aspects as transferring and preserving knowledge, exchanging information, establishing and supporting cooperative networks, and training the next generation of nuclear experts. Academic institutions have significant opportunities to apply knowledge management practices to support their activities in preparation of highly qualified specialists too.

Development of knowledge management in universities let us provide immediate access to education materials and teaching experience, work towards skills development , eliminate the gaps in education and training, at least if done effectively, it can lead to a big progress in engineering.

This paper describes building of knowledge management system in National Research Tomsk Polytechnic University and shows the Scientific and technical information portal (STIP) is created by authors in cooperation with Russian Federal Atomic Energy Agency. STIP has the form of library, which collects all scientific research, projects, employees and students’ publications; in addition, it consists of work experience of last generations. All this information is available for both employees and student.

At the beginning of scientific work, a researcher spends eighty percent of time for solving old tasks and just twenty percent for searching innovation solutions. Thanks to the STIP this proportion can be changed exactly the opposite.

1. Introduction

The problem of knowledge loss is the issue of the present day in all types of industry. Special attention should be paid to nuclear industry. Nuclear energy technologies have a long life cycle, an obvious example is a nuclear power plant. Designing of a nuclear power plant takes at least ten years; its construction is also a long-term process, which needs the required knowledge and past experience. The next step is operation of nuclear power plant and the last one is shutdown. The whole process requires fixing of stored knowledge in the process of operation and in addition, it requires build-up and improvement of knowledge. For example, Fermi identified the concept of fast reactors development in 1944. In 1946, an experimental plutonium-fuelled reactor was created (Climentina, USA). To date, over twenty experimental and development fast breeder reactors have been created, the first industrial prototypes of fast power reactors, cooled by liquid metal (sodium), are in operation: in Russia (BN-600), France (PHENIX). These facts required knowledge transfer to the next three generations of researchers. Countries, which had no knowledge transfer of fast neutrons reactors technologies and closed nuclear fuel cycle, lost this knowledge considerably. The losses of experience and knowledge are not just economic losses. It is full-on scientific and technology disaster, which consists of losses of skilled workers, strong system of higher education, research and trial facilities, generation of young researchers. It may take decades for the government to recoup the losses.

Often, the knowledge and experience of past years have not been documented. The reason for the loss of nuclear knowledge, can serve a variety of factors such as aging of employees, decline of technological skills and loss of know-how, potential reduction in the safety and feasibility of innovation potential disappearance. In reference with the above nuclear knowledge stakeholders such as governments, international organizations, and industry have a vigorous activity in development of knowledge management. It includes strategies and programs to collect, exchange, store and transfer information to new generation.

Incidentally, knowledge management is needed to be applied to academic institutions too. Knowledge management formation in National Research Tomsk Polytechnic lets us provide an access to legacy of the past, present and future of nuclear industry.

2. IAEA and nuclear knowledge management

The IAEA nuclear knowledge management activities assist in transferring and preserving knowledge, exchanging information, establishing and supporting cooperative networks, and training next generation of nuclear experts. These activities in assisting Member States in the preservation and enhancement of nuclear knowledge and in facilitating international collaboration have been recognized by the General Conference of the International Atomic Energy Agency. Much work has been done by the IAEA in addressing the knowledge management needs of different nuclear organizations [1].

3. International experience

Experience of other international organizations, not just in nuclear industry, shows there are no universal systems of knowledge management for any kind of organisation. Each system has unique elements, tools and technologies. All knowledge systems is developed according to the purposes of a company, kind of activity and specificity of company`s knowledge. For the moment, the concept of knowledge management is integrated in developed global scale companies. This can be exemplified by Siemens AG, where in 1999 an information exchange system ShareNet29 started operating in Siemens Information and Communication network (ICN) [2]. The next example is Skanska Group, which has IT-platform called Skanska Knowledge Network [3]. Skanska Knowledge Network helps corporate employee to find necessary information in inhouse database. The example of application of nuclear knowledge management system is Canadian project CANTEACH [4]. This knowledge repository provides high quality technical documentation relating to the CANDU nuclear energy system. The CANTEACH Project aims to provide an information exchange network for people interested in the CANDU energy system. Contributors are industry experts who hold valuable knowledge and experience in diverse aspects of CANDU technology and its applications, and unique expertise in the areas of science and technology, nuclear power design and construction, project management and development of engineering tools [4].
Consequently, one of the main points of successful usage of stored knowledge is systematization and management. Nuclear industry needs individual approach for integration of knowledge management system.

4. Nuclear knowledge management system in National Research Tomsk Polytechnic University

National Research Tomsk Polytechnic University (TPU) is one of the leading nuclear universities of Russia. Today TPU consists of twelve institutes, thirteen management units and has its own nuclear reactor. Also, the university is included in association of consortium of main academic institutions of Rosatom State Atomic Energy Corporation (Rosatom). Rosatom is integrating nuclear knowledge management system in all branches of company.TPU with such complex organizational structure has a significant knowledge and information flow. This flow needs to be managed. The goal of the present work is to investigate the Rosatom`s experience in creating of nuclear knowledge management system and, as a result, integrate this system in the Institute of Physics and Technology (IPT). The

introduction of the concept into the structure of the Institute will provide access to the existing legacy of nuclear expertise, ensure the transfer of knowledge to a new generation, and will fill the gaps emerged in connection with the loss of nuclear knowledge.
Organizational structure of IPT is detailed in figure 1. The structure includes Academic office, Science office, Material Properties Measurements Centre (MPMC), Engineering support office, Nuclear research rector, Information office. In addition, the institute consists of eleven departments and seventeen laboratories. Authority of IPT is headed by the Director, Deputy Director for Academic Affairs and Deputy Director for Research.

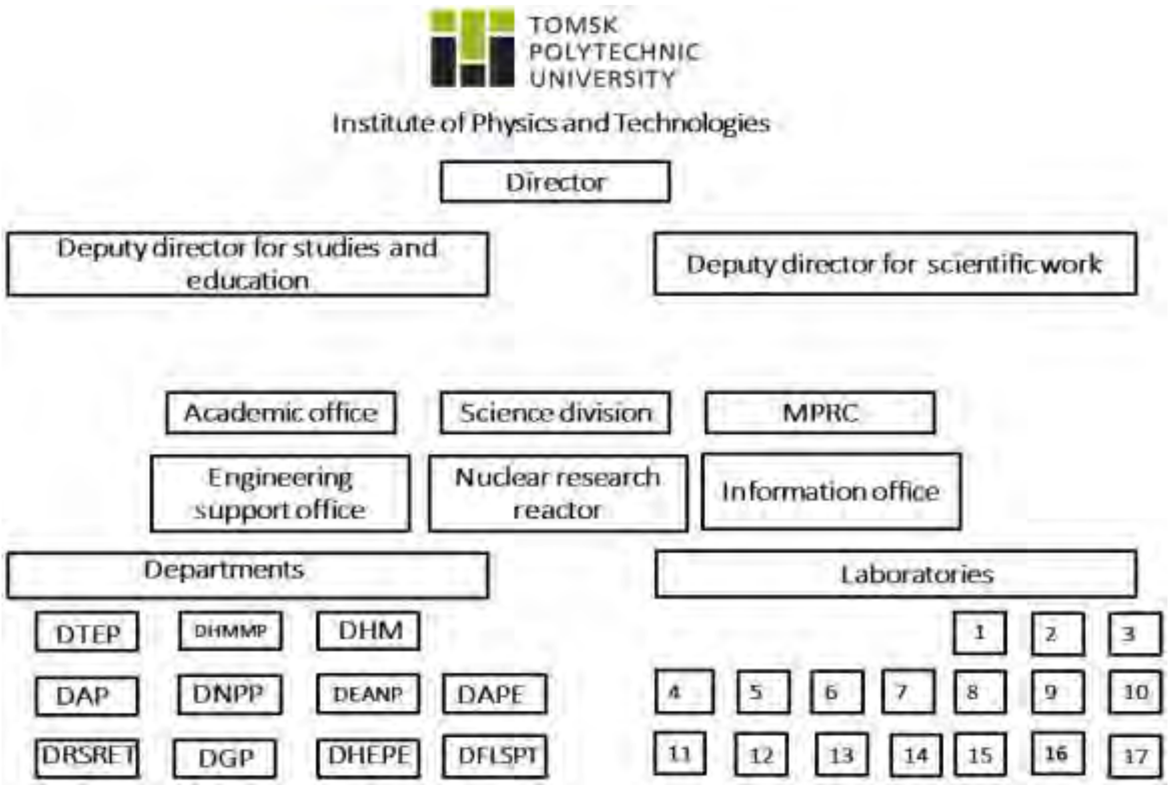

Fig 1. Organizational structure of Institute of Physics and technologies

R&D results obtained by IPT staff and students need to be structured and preserved. The diagram of knowledge generation processes is shown on figure 2.

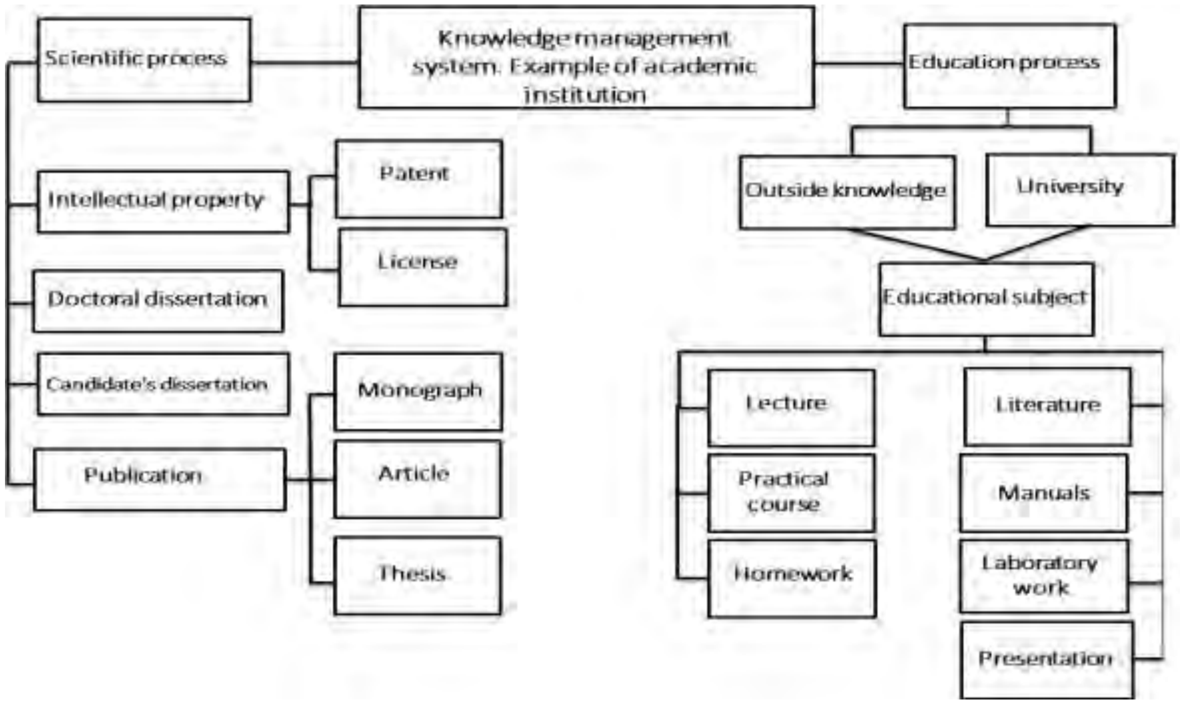

Fig 2. Information processes

Scientific and technical information portal of IPT has the form of library, which collects all scientific research, projects, IPT employees and students' publications; in addition, it consists of work experience of last generations. All this information is available for both employees and students, thereby reducing the time for information search.
Using a web-browser users connect to the portal and can perform the following actions:
• view information collections;
• add, edit and delete the items in information collections;
• perform a full-text, attributive search, and a search using the industry classifier or the thesaurus;
• create permanent thematic queries;
• use the "Calendar of scientific and technical activities".
Home page includes general information about this project, a newsportal, and materials of knowledge management system with operating manual and history of the project. One can also find contact information, and technical support line, where users can seek the advice of the portal content administrators and technical experts on issues related to the preparation of documents and their posting on the Scientific and Technical Information portal.
Portal includes nine information sections (figure 3).
1. Publication. This section includes articles, reports, presentations of employees and students that were publish in national and foreign journals.
2. Repository of scientific and technical documentation. Catalogue of digitized scientific and technical documentation of the Institute (research paper, developmental work. Inoperative patents, etc.).
3. R & D works ready for commercialization.
4. Intellectual property. This section consists of IPT employees' intellectual property.
5. Content of scientific events. This section consists of conference, seminar, and symposium information.
6. Specialists. The details about specialists of IPT in different scientific fields.
7. Scientific online resource. Hyperlink for informative sources.
8. Trade journals.

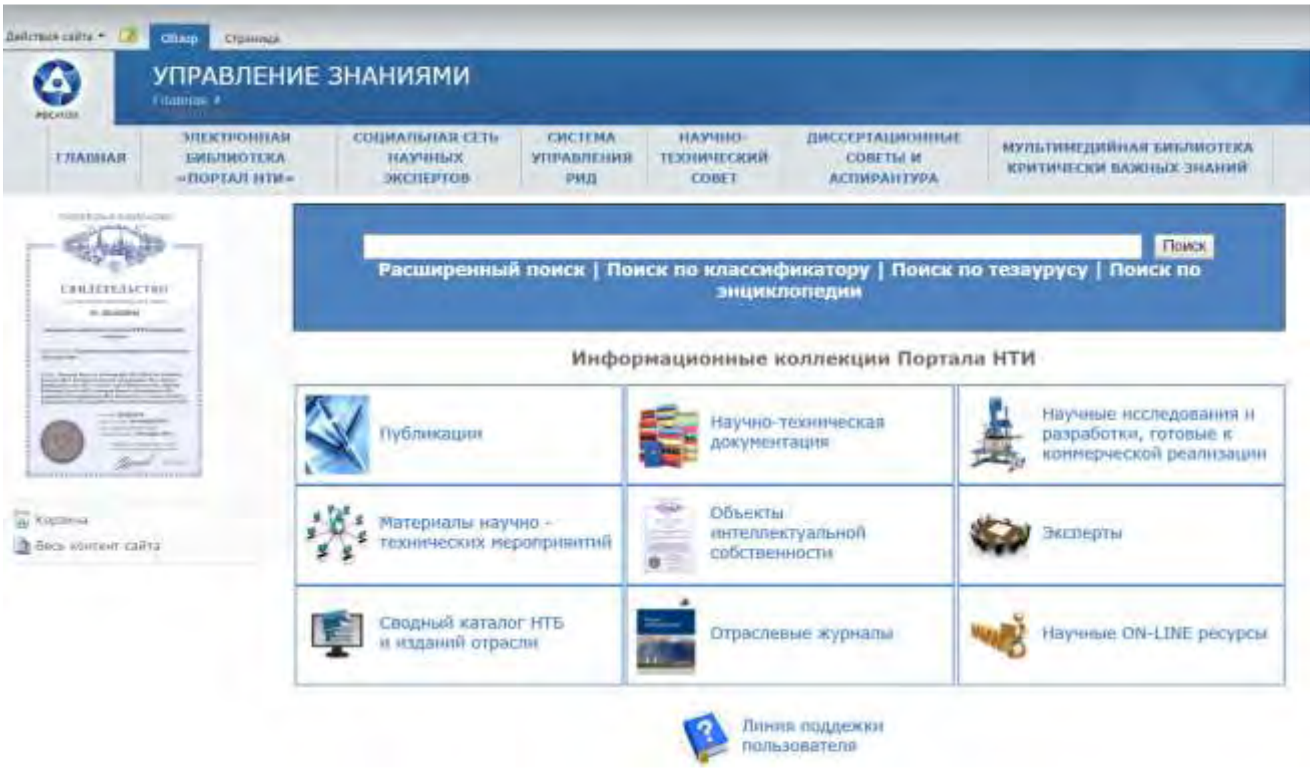

Fig. 3. Scientific and Technical Information portal of IPT

5. Conclusion

At the beginning of scientific work, a researcher spends eighty percent of time for solving old tasks and just twenty percent for searching innovation solutions. Thanks to the Scientific and Technical Information portal of IPT this proportion can be changed exactly the opposite. Currently, TPU is integrating into knowledge management system of Rosatom. The process of developing IPT system is on the early stage. Digitisation of IPT stored knowledge and filling-in of the library have already started. After successful application in IPT, it is planned to expand and integrate the system into all institutes of TPU.

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How to ensure that enough motivated and competent workforce is available for the nuclear sector?

THE CHALLENGE OF TOO FEW JOBS FOR QUALIFIED NUCLEAR POWER GRADUATES: A TEXAS RESPONSE

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ABSTRACT

To meet the anticipated manpower needs of the nuclear power industry in Texas, nuclear power technology training programmes were developed or expanded at several community colleges in the region beginning in 2007. However, retirements of technologists at nuclear power facilities in Texas and elsewhere in the USA have not occurred at the high rate originally projected by the nuclear power industry in 2007. As a result of this, graduates of Texas programmes are facing very limited employment opportunities, and this unfortunate prospect has led to significant declines in enrollments in the nuclear technology training programmes in Texas. In order to provide additional employment options for students enrolled in its nuclear training programs, the administrators of the programme at Wharton County Junior College began awarding Level 2 Certificates in the operations, electrical, instrumentation and controls, and mechanics specialisations. These actions were taken to ensure that graduates of the nuclear programme would have additional credentials and skill sets needed to obtain nuclear employment or alternative employment in other high demand industries in Texas, such as the non-nuclear energy, petrochemical, and manufacturing industries.

1. Introduction

In March 2007 the U.S. Department of Labour (DOL) published *Identifying and Addressing Workforce Challenges in America's Energy Industry* [1], which discussed the energy industry's needs for new workers, who would be recruited and trained with new skill sets in the coming 10 years. It also noted that the average energy industry worker in the USA was over 50 years of age and that approximately 50% of them were planning to retire within five to ten years. That meant that there would be a need to replace approximately 500,000 energy employees nationwide. In addition to the DOL assessment, two other workforce survey reports pointed out the same concerns. These survey reports included *Gaps in the Energy Workforce Pipeline* [2] by the Centre for Energy Workforce Development (CEWD) and *2007 Workforce Pipeline Survey* [3] by the Nuclear Energy Institute (NEI).

These surveys and reports were issued just prior to the worldwide financial recession that began in 2008, which has had long lasting effects on the energy workers eligible for retirement. In the USA, many of the energy workers have individual retirement plans that were almost exclusively invested in the stock market. During the worldwide recession, many individual retirement plans lost significant value. This was an enormous setback for those planning retirement, and it forced many of the workers to continue working instead of retiring. Today the average energy industry worker is nearing or has exceeded age 60 and the projected retirements are not occurring. Because of so few job openings, the enrollments in the nuclear power technology training programs in Texas have declined.

A possible disconcerting result is that the orderly and timely transfer of knowledge of nuclear power plant operations and maintenance functions might not be occurring as originally envisioned in 2007. The current aging workforce is still at the controls of the power generation plants, while the next generation of young workers is not yet being recruited and trained in sufficient numbers to operate and maintain the power plants.

2. Training Programs in Texas

The NEI workforce report noted that Texas would need three new nuclear power plant maintenance training programmes and at least one new non-licensed operator training programme. At the time of the NEI study, Texas had only five generic nuclear training programmes and one radiation protection programme. Based solely on estimates of retirements and normal attrition, NEI recommended that two of the existing generic programmes be restructured to comply with the Institute of Nuclear Power Operations' *Uniform Curriculum Guide for Nuclear Power Plant Technician, Maintenance, and Nonlicensed Operations Personnel Associate Degree Programmes* (ACAD 08-006) [4] for maintenance staff and that another programme to be restructured for operators.

In response to the specific needs of the nuclear power industry in southeast Texas, representatives of industry and economic development boards formed the Midcoast Industry and Education Alliance in 2006 to explore ways to promote nuclear technology programmes in southeast Texas. From this alliance evolved the Texas Nuclear Power Technician Programme Partnership that was formed in 2007-2008. This partnership was a coalition of key stakeholders, including community colleges, industry partners, universities, professional organizations, community-based organisations and civic groups, school districts, chambers of commerce, and economic development agencies. The purpose of the coalition was to address two critical issues, namely, (1) the lack of adequate nuclear power technology training facilities, faculty, instructional equipment, and curricula aligned with industry standards that were needed to educate and train workers to meet industry needs and (2) the need for community colleges in southeast Texas to develop uniform accredited nuclear power technology curricula and to expand industry-specific certificate, associate, and baccalaureate degree programmes.

To fulfill industry needs, the partnering colleges required well-trained faculty to develop and teach curricula aligned with industry standards and in compliance with the *Uniform Curriculum Guide* (ACAD 08-006) of the Institute of Nuclear Power Operations (INPO). The community colleges realised that they would need to upgrade equipment to provide adequate classroom and laboratory training that would meet industry standards and comply with the *Uniform Curriculum Guide*. The colleges also realised they would need to develop comprehensive recruitment and retention strategies to attract and retain students in the newly developed and expanded nuclear power technology programmes.

3. Literature Review

The theoretical basis for this report included organisational behavior studies of the institutionalisation of organisations [5,6,7,8], organisational change [9], organisational development [10,11], and organisational alignment with the environment [12]. It also included examination of the effort to establish nuclear training programmes at community colleges as an example of a community-based "coalition" in action. Community participation in health, safety, community development, and educational planning is noted in numerous theoretical perspectives found in the literature of organisational behavior.

Community participation in health, safety, and community development planning (including planning for education programmes) occurs through a variety of community-based advisory groups, but especially through community-based coalitions. These 'coalitions' can be loosely defined as a group of individuals representing diverse stakeholders (i.e., organisations, factions, or constituencies) within a community who agree to work together to achieve a common goal (adapted from Feighery and Rogers) [13].

Community participation in health, safety, social, and educational projects can take a variety of forms, and there can be variations in the extent of community participation. It has been found that community-based coalitions as organisations have many of the characteristics of 'minimalist organisations' as defined by Halliday, Powell, and Granfors [14,15] and can demonstrate progression through the stages of development noted by Aiken et al. [16]. Studies of community participation through the use of community-based coalitions have demonstrated repeatedly that these organisations have been successful in addressing a variety of health and social issues, including educational needs in communities. Coalitions as organisations are highly flexible and can engender strong support locally from the communities participating in this type of planning process.

Butterfoss [17] noted that the concepts and assumptions underlying community development, citizen participation, empowerment, community capacity, community competence, and social capital provided the groundwork for the coalition as a community-organising model and as a strategy for resolving community issues and achieving community goals [17: p.12]. It also noted that community coalitions have 'the potential to involve multiple sectors of the community and to conduct multiple interventions that focus on both individuals and their environments' [17: p.16] and that community coalitions are 'a promising strategy for building capacity and competence among member organisations and, ultimately, in the communities they serve' [17: p.17]. This is true of coalitions focusing on health issues as well as coalitions focusing on educational and job-skills training issues.

In an examination of the principles of collaborating and partnering in community health contexts, Butterfoss [17] developed definitions of collaboration, identified the intensity of collaboration, provided models of collaboration, and provided an explanation of the types of coalitions. The Texas nuclear power technology partnership has characteristics of several types of coalitions, including those pertaining to community-based coalitions of professional and grassroots members and action-set coalitions. The IAEA found that this type of integration and partnership is very conducive to the development of sustainable nuclear technology training programmes [18].

4. Methodology

This qualitative study of the establishment and development of the nuclear power technology programmes at community colleges in southeast Texas (namely, Wharton County Junior College and Brazosport College) has been ongoing since 2007. It is utilizing a variety of observational research methods, including attending and participating in planning meetings; attending and participating in specific subcommittee meetings; interviewing members of the coalition; interviewing key participants (including representatives of educational institutions, nuclear utilities, local economic development boards, civic organisations, and interested citizens); assisting with drafting applications for financial support from local, state, and federal sources; and examining documents related to the operation of the programmes since their inception in 2007-2008. It also includes attendance at conferences sponsored by the Nuclear Energy Institute (NEI), the Centre for Energy Workforce Development (CEWD), the Conference on Nuclear Training and Education (CONTE), and the High Impact Technology Exchange Conference (HI-TEC).

5. Nuclear Power Technology Coalition Members

The following colleges, utilities, universities, economic development boards, state and federal agencies, school districts, and groups were important stakeholders in fostering and gaining community-wide consensus concerning establishment of nuclear power technology programmes at community colleges in southeast Texas.

Table 1: Stakeholders and Types of Organisation

1. Community College Partners: Brazosport College, Wharton County Junior College, Victoria College, and Texas State Technical College
2. University Partner: Nuclear Power Institute, Texas A & M University

3. Professional Association Partner: Health Physics Society
4. Industry Partners: South Texas Project Nuclear Operating Company and Excelon Corp.
5. Industry Association Partners: Nuclear Energy Institute (NEI), Washington DC and Institute of Nuclear Power Operations (INPO). Atlanta GA
6. Industry Association Partners: LyondellBasell and Celanese Chemicals
7. Energy Industry Partner: NRG Energy
8. State Partners: Texas Office of Economic Development and Texas Workforce Commission
9. Economic Development Partner: Bay City Community Development Corporation, Economic Development Alliance of Brazoria County, Victoria Economic Development Corporation, Wharton Economic Development Corporation
10. Business Association Partners: Chambers of Commerce & Agriculture of Wharton, Brazosport Area, Victoria, and Greater Waco
11. School District Partners: Bay City, Brazosport, Calhoun, El Campo, Victoria, Waco, Wharton Independent School Districts
12. Community Partners: Boys and Girls Club of Brazoria County, Christian Women's Job Corps, Victoria Business and Education Coalition, and Golden Crescent Workforce Development Board

6. Implementation of the Nuclear Power Technology Plan for Southeast Texas

The four colleges in the Texas nuclear technology training partnership included Wharton County Junior College, Brazosport College, Victoria College, and Texas State Technical College. These colleges jointly explored ways to obtain funding to develop and operate new or expanded nuclear power technology programmes. They sought funding to hire faculty, purchase state-of-the-art nuclear technology instructional equipment and simulation software programmes, and develop curricula that would comply with the *Uniform Curriculum Guide* (ACAD 08-006). Approvals for the colleges to develop new training programmes and expand current ones were quickly obtained from the Texas Higher Education Coordinating Board, which oversees academic and vocational training programmes in Texas.

Texas Agricultural and Mechanical University (i.e., Texas A&M University) provided significant assistance and guidance to the colleges as did the South Texas Project Nuclear Operating Company (an industry partner). Initially, the Texas Engineering Experiment Station at Texas A&M University provided 'start-up funding' as well as guidance in obtaining federal funding. The Nuclear Power Institute (NPI) at Texas A&M played a major role in providing guidance to the Wharton programme and in advocating for it at national and international meetings. The NPI made extraordinary efforts to highlight the achievements and quality of the nuclear power programme at Wharton County Junior College (WCJC) and arranged for Mr.Rudolph Henry, Director of Nuclear Power Technology Programme at WCJC, to participate in the September 2012 General Conference of the International Atomic Energy Agency. While at the conference, Mr.Henry met the leadership of IAEA and representatives of several national delegations, many of whom wanted to know more about the Wharton programme. The NPI also arranged for Mr.Henry to present a report in December 2012 concerning nuclear power technology programmes to members of the U.S. Congress, congressional staff members, the Deputy Secretary of Energy, and the Assistant Secretary for Nuclear Energy in Washington, DC. Discussions were also initiated in 2012 concerning admission of students from overseas into the Wharton programme and development of internships at the South Texas Project Nuclear Operating Company for these students. [Personal communication with Dr.Kenneth Peddicord, Fall 2012.]

7. Support from Industry Partners

The South Texas Project Nuclear Operating Company (STPNOC), as the industry partner, played a major role in the effort to establish nuclear power technology programmes at community colleges in southeast Texas. It facilitated meetings of the Midcoast Industry and Education Alliance, which led to the formation of the educational coalition in support of nuclear training programmes. To assist the college programmes, STPNOC provided timely letters of support, in-kind support, and an educational incentive programme for entry-level employment at STPNOC. The incentive programme is an effort to award grants, through a competitive process, to students enrolled in the nuclear technology programmes. Students selected for the award receive additional trainings at the STP facility during internships.

A second important industry partner in promoting and facilitating the establishment of nuclear power technology programmes at community colleges in southeast Texas was the Nuclear Energy Institute (an industry association), headquartered in Washington, DC. Both the Wharton and the Brazosport programmes were developed in strict compliance with the *Uniform Curriculum Guide* (ACAD 08-006), which requires adherence to a standardised curriculum for training nuclear power plant technicians.

8. Funding for Nuclear Power Technology Programmes in Southeast Texas

Since 2008, the Wharton and Brazosport nuclear power technology programmes have been the recipients of grants from federal, state, university, and economic development agencies. These grants focused on upgrades to laboratory equipment and development of curricula and included major grants from the Bay City Community Development Corporation ($4,500,000), residents of Bay City ($1,500,000), Texas A&M University ($105,000), Jobs & Education for Texans (JET) Program ($350,000), American Recovery and Reinvestment Act Programme ($175,000), U.S. Nuclear Regulatory Commission ($355,780 for curriculum development), and U.S. Department of Education ($220,000). Additionally, since 2009, the U.S. Nuclear Regulatory Commission has provided more than $1,000,000 in scholarship funds for students specialising in nuclear power studies at the Wharton and Brazosport programmes.

The award from the U.S. Department of Labour ($1,888,487) was shared by the four colleges that originally participated in the Texas nuclear power training coalition. However, Victoria College withdrew from the partnership in 2011 after plans for constructing a nuclear power generating facility in its service area were cancelled. The training programme at Texas State Technical College is focused on radiation protection.

The benefits of the original U.S. Department of Labour (DOL) grant to the Texas nuclear power technology educational partnership were significant, including:

- **Instructor Training:** The DOL grant provided funding for faculty members to receive an average of 120 hours of training at the South Texas Project Nuclear Operating Company (the industry partner), under the supervision of nuclear subject matter experts.
- **Curriculum Development:** The DOL grant provided for the faculty of the participating colleges to work with South Texas Project administrators to develop and modify curricula to conform to the *Uniform Curriculum Guide* (ACAD 08-006) of the Institute of Nuclear Power Operations. Additional funding for curriculum development was provided by the Nuclear Power Institute, the U.S. Nuclear Regulatory Commission, and the U.S. Department of Education.
- **Laboratory Development:** The DOL grant provided support for significant upgrades of laboratory facilities used in conjunction with the curricula for the nuclear power technology programmes. These included funding for nuclear instructional equipment, workstations, computer-based simulators, and ‘hands-on’ training skids (i.e., ‘HOT skids’), which ensure that students are being trained to use and operate the same state-of-the-art technology as currently found in the power generation industry.

9. Wharton and Brazosport Nuclear Power Technology Programmes

At the conclusion of the Department of Labour project, the Wharton and Brazosport programmes continued their partnership. Both colleges are public, two-year community colleges that are fully accredited by the Commission on Colleges of the Southern Association of Colleges and Schools. The colleges are authorised by the Texas Higher

Education Coordinating Board to offer Associate of Arts and Associate of Applied Science degrees and curricula in preparation for baccalaureate programmes. Brazosport is authorised to award a baccalaureate degree. The Wharton and Brazosport service areas extend across eight counties, and the South Texas Project Nuclear Operating Company is located within the region served by the two colleges.

Wharton Nuclear Power Technology Programme. The Wharton programme offers an Associate of Applied Science degree in Nuclear Power Technology with four degree options, namely, (1) Non-Licensed Operator, (2) Electrical Technician, (3) Instrumentation and Controls Technician, and (4) Mechanical Technician. It also offers an Enhanced Skills Certificate in Nuclear Power Technology upon completion of the Associate of Applied Science degree in Process Technology and completion of the required nuclear technology courses. During the 1st year of studies, all students enroll in courses in nuclear power plant fundamentals and operations. They select a specialisation track in their 2nd year.

Table 2: Course Requirements for All Specialisations (during 1st Year)

Fall Semester (all students)		**Spring Semester** (all students)	
Course	**Course Title**	**Course**	**Course Title**
NUCP 1371	Math & Chemistry Fundamentals for Nuclear Power	NUCP 1370	Nuclear Fundamentals I
ELPT 1370 or PTAC 1302	Introduction to Power Technology or Introduction to Process Technology	NUCP 1471	Nuclear Fundamentals II
BCIS 1305	Business Computer Applications	PTAC 1432	Instrumentation I
MATH 1314 or MATH 2312	College Algebra or Pre-Calculus	CHEM 1405 or CHEM 1411	Introductory Chemistry or Chemistry I
ENGL 1301	Composition & Rhetoric I	NUCP 1472	Nuclear Power Plant Organisation & Processes

During the 2nd year of studies, students select one of the following four options:

- Option 1. Non-Licensed Operator: DC-AC Circuits; Nuclear Power Plant Systems I and II; Principles of Quality; Digital Measurements & Controls; Social Science Elective; Humanities Elective; Critical Thinking & Problem Solving; Discipline-related Elective; Public Speaking; and Cooperative Education (Internships at STP).
- Option 2. Electrical Technician: AC/DC Circuits; AC/DC Motor Controls; Digital Measurements and Controls; Electromechanical Systems; Principles of Quality; Electronic Troubleshooting, Service, & Repair; Social Science Elective; Humanities Elective; Public Speaking; Critical Thinking & Problem Solving; and Cooperative Education.
- Option 3. Instrumentation and Control Technician: AC/DC Circuits; AC/DC Motor Controls; Digital Measurements and Controls; Principles of Quality; Power Generation Instrumentation; Instrumentation II; Social Science Elective; Humanities Elective; Public Speaking; Critical Thinking & Problem Solving; and Cooperative Education.
- Option 4. Mechanical Technician: Industrial Maintenance; Pumps, Compressors, & Mechanical Drives; Shielded Metal Arc Welding; Testing & Inspection Systems; College Algebra or Pre-Calculus; Hydraulic Fabrication & Repairs; Public Speaking; Process Instrumentation; Computer Numerical Controlled Machine Controls (CNC); and Special Topics in Manufacturing Technology.

The Wharton training programme includes lectures as well as laboratory exercises. It offers training through the use of state-of-the-art equipment, 'hands-on' training skids ('HOT skids'), and computer-based simulators. The simulation exercises reinforce lecture material and provide an opportunity for faculty to train students to become familiar with plant start-up and shut-down processes, plant operations, and analysis of common problems at nuclear power plants. 'Hands-on' training is provided through the use of actual nuclear power generation equipment. Students also learn electrical, instrumentation, computerized numerical control machining, non-destructive testing, welding and oxygen cutting, and hydraulics skill sets through use of modern industrial laboratory equipment.

Instruction by and interactions with Subject Matter Experts (SMEs) from the South Texas Project nuclear power plant are important components of the Wharton programme. Wharton's inclusion of SMEs in the development of curricula and in instruction was recognized by the International Atomic Energy Agency (IAEA) when it noted in its *Status and Trends in Nuclear Education* [18] that the Wharton programme was a 'best practice' programme among two-year nuclear power technology training programmes. Due to this international recognition, the IAEA and the Nuclear Power Institute at Texas A&M University periodically facilitate visits to the Wharton programme by governmental and energy industry representatives from countries interested in developing similar training programmes. Recent visitors included representatives from Czech Republic, Japan, China, Kenya, Vietnam, Uganda, Niger, Turkey, Thailand, Nigeria, Indonesia, and Bangladesh.

Brazosport Nuclear Power Technology Programme. The training programme at Brazosport College offers an Associate of Applied Science degree in Chemical Technology (Process Operations Option) that includes a Nuclear Power Specialty with Enhanced Skills Certification. The programme is designed to train students in the essential skills that are needed to work in the nuclear power generation industry. Courses include mathematics, chemistry, process technology, as well as nuclear fundamentals and nuclear power generation technology, including the following:

Table 3: Nuclear Power Specialty with Enhanced Skills Certification

Course	Title
ELPT 1370	Introduction to Power Generation Technology
NUCP 1370	Nuclear Fundamentals I
NUCP 1371	Mathematics & Chemistry Fundamentals for Nuclear Power
NUCP 1471	Nuclear Fundamentals II
NUCP 1472	Nuclear Power Plant Organisation and Processes
NUCP 2470	Nuclear Power Plant Systems I
NUCP 2471	Nuclear Power Plant Systems II

Brazosport College also offers a Bachelor of Applied Technology degree that is designed to broaden career opportunities and better prepare nuclear power trainees for promotion to supervisory positions. The upper division classes expand students' understanding of business operations (including management, human resources, accounting, legal issues, and technology). Coursework incorporates internships and other practical real-world learning activities to ensure that students acquire technical competencies and managerial skills in order to be effective supervisors.

Additional Information about the Programmes. The Cooperative Education courses (i.e., NUCP 1380 and NUCP 1680) provide options for internships at nuclear power facilities. A student can select NUCP 1380 for a 16-week internship at a nuclear power facility during a regular semester. After the AAS degree requirements have been completed, a student can select NUCP 1680 for a 7-month internship at a nuclear facility.

Students participating in the Wharton and Brazosport training programmes may be eligible to receive a National Academy for Nuclear Training Certificate (NANT Certificate) upon graduation. This certificate is administered jointly by the Institute of Nuclear Power Operations (INPO) and the National Academy of Nuclear Training (NANT) in collaboration with each college and its nuclear industry partner. To be eligible for this certificate, students must obtain a minimum passing grade of 80% in all required courses.

10. State-of-the-Art Instructional Equipment

The courses offered at the Wharton and Brazosport programmes are aligned with the *Uniform Curriculum Guide* (ACAD 08-006) for training nuclear technicians, including operations, electrical, and instrumentation/control technicians. Experiential learning exercises are designed to be almost identical to actual on-the-job industry training, job shadowing, and industry discipline. In addition to course work in nuclear power technology fundamentals, the programmes include 'hands-on' laboratory exercises as reinforcement for classroom lectures. This experiential learning component includes training on state-of-the-art instructional equipment such as the following:

- ABB Digital Fieldbus Technology Demo Box
- Hampden Boiler/Turbine Generator Power Distribution Skid
- Intellitek Electrical Training Modules
- Computer-based simulators for operating Pressurised Water Reactors (PWRs) and Advanced Boiling Water Reactors (ABWRs)

The computer-based simulation exercises reinforce lecture material and facilitate experiential learning for the students by providing opportunities for 'hands-on' use of actual state-of-the-art nuclear power generation equipment. Training modules have been developed that integrate computer-based nuclear power plant simulation applications into the training programmes. The computer-based nuclear power plant simulations provide an opportunity for faculty to train students to become familiar with plant startup and shutdown, plant operations, and analysis of common problems at nuclear power plants. The curriculum developed for operating PWRs and ABWRs at nuclear power plants has been made available through the Nuclear Energy Institute for distribution to other educational institutions offering training programmes in nuclear power technology.

11. Programme Results

The Wharton and Brazosport training programmes have been successful in recruiting and training students, who will become the next generation of highly skilled workers in the nuclear power generation industry in southeast Texas and elsewhere in the USA. The following table shows the accomplishments of these training programmes.

Table 4: Wharton and Brazosport Nuclear Programmes – Combined Results

	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
Enrollments									
Total Students	13	72	140	116	109	87	57	45	70
Gender									
Male	11	58	117	93	90	70	49	32	57
Female	2	14	23	23	19	17	8	13	13
Race/Ethnicity									
White non-Hispanic	10	46	92	75	68	57	34	22	34
Hispanic or Latino	3	19	29	32	31	22	15	15	28
Black non-Hispanic	--	1	5	8	8	8	6	6	7
Other	--	6	14	1	2	0	2	2	1
Graduates of the Nuclear Technology Programmes									
Associate Degree	--	5	43	22	33	33	17	11	n/a
Certificate	--	4	12	6	6	1	5	1	n/a
Status Post-graduation									
In Nuclear	--	5	32	10	9	4	7	7	n/a
In Non-Nuclear	--	--	2	13	30	24	9	1	n/a
In Other Studies	--	--	7	2	3	3	--	--	n/a
Unknown	--	4	14	3	3	3	1	8	n/a

Diversity in enrollments and graduations is an important goal for the Wharton and Brazosport programmes and both colleges have made efforts to foster gender, racial, and ethnic diversity in their programmes. Beginning in 2009-10, diversity in enrollments was achieved, with approximately 35% (or more) of enrollments being students from the racial and ethnic minority communities in the region.

12. Changes in the Wharton Program

When the administrators of the Wharton training program realised that enrollments were declining because of limited employment opportunities in nuclear, they quickly identified a need to award Level 2 Certificates in each of the nuclear specialisations, including operations, electrical, and instrumentation and controls. In addition to these specialisations, the college developed a new Manufacturing Technology program that now offers a mechanical specialty. Students in the nuclear training program can enroll in the mechanical specialty, which also offers a Level 2 Certificate. These certificates ensure that the graduates have additional credentials and skill sets needed to obtain either nuclear employment or alternate employment in other high demand industries.

Students can choose to specialise in the Non-licensed Operator, Electrical Technician, and Instrumentation and Control Technician tracks or in the new Mechanical Technician track. All students enrolling in these 'mechatronics' specialisations – both those in Nuclear Power Technology and those in Manufacturing Technology – have the opportunity to earn a college-issued Level 2 Certificate in their chosen specialisation upon completion of the course requirements.

After completing the 1-year mechatronics certificate program, graduates of either programme will have the credentials and skill sets needed to enter employment immediately. Students majoring in Nuclear Power Technology can apply for nuclear power plant positions as well as for positions in non-nuclear energy or other high demand industries in the region. Students majoring in Manufacturing Technology can apply for technician positions in petrochemical or manufacturing industries, or they can enroll in a second year of industry-related training leading to an associate's degree in Manufacturing Technology. Another option for them is to enroll in the first year of studies in the Nuclear Power Technology programme, which can lead to an associate's degree and possible employment at a nuclear power plant.

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THE NUCLEAR TRAINEES PROGRAM:

A STRONG ENGIE BANNER

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ABSTRACT

The ENGIE Group has launched the NUCLEAR TRAINEES PROGRAM (NTP) in 2006 after being faced with the retirement of the staff who took part in the Belgian NPP's design, building commissioning and first operation years, the closure of the nuclear engineering branch at the Belgian Universities and High Schools and the war for talent for young engineers in general.
Initially, the program had been developed for young engineers (NTP-Junior), freshly graduated new comers in the Group; the 10th session started this year. In total, already 690 engineers have followed this program. Later on, other more condensed programs have been tailored to other specific needs: NTP-Major for experienced engineers who's career is reoriented into the nuclear field, NTP-Generation for operational engineers, NTP-Support for support functions (HR, ITS, COM), NTP T for Technicians.
The NTP-J technical program is spread over 7 full week class room courses, covering the whole value chain of nuclear electricity generation, according to the needs of the entities of the Group, in particular: Radioprotection, PWR technology, neutronics, thermal-hydraulics, material corrosion and behaviour under irradiation, nuclear safety, fuel cycle, waste and decommissioning, maintenance,…. The program is moreover completed with technical visits and trainings in simulator.
The teachers are either chosen in the Group staff, or are coming from external companies:, the Belgian nuclear research centre in Mol (SCK.CEN), AREVA, Corys, …. They are selected by a Committee for their technical skills as well as for their pedagogical skills: as the program is addressed to young professionals interactivity is a key point of the value of the course.
NTP-J also includes behavioural learning programs: communication and leadership, presentation skills, , …. And, last but not least, the networking between colleagues of all entities of the group is largely encouraged and made possible through the mixing of the teams from one week to the other, and through various Global Meetings.
The knowledge acquisition is measured through tests before the program, after each course and at the end of the year. The tests are multiple choice questionnaires selected in the large set of questions that the trainees have access to for daily training. The qualification of the questions follows a comprehensive process by the teachers and external experts, also taking into account the experience feedbacks.
The training is recognized by the Belgian Safety Authorities as meeting requirements of the Safety Analysis Report.

1. Introduction

The ENGIE Group covers the whole value chain of the nuclear sector, going from nuclear project development, over engineering and construction of Nuclear Power Plants, operations and maintenance in NPP's, nuclear services activities, fuel and waste management, and dismantling activities:

- ENGIE Electrabel: one of the largest electricity producers in Europe, with 7 nuclear power plants in Belgium. The nuclear electricity production represents in the ENGIE Group 5,2% of it's installed generating capacities in electricity, and remains part of the activity portfolio for the coming years.
- ENGIE Axima is a recognized expert in ventilation of nuclear facilities
- Endel ENGIE: has activities throughout the life cycle of nuclear facilities, from their development up to their dismantling, through their operation and maintenance.
- ENGIE Fabricom: reference in matters of technical installations and services for industry sectors and infrastructure.
- ENGIE INEO: has all the certifications and qualifications and operates on all the sites classified as "basic nuclear installations".
- Tecnubel: offers a wide range of services to nuclear operators (Logistics, technical management of nuclear facilities ...).
- Tractebel ENGIE: active as architect engineer, owner engineer or consulting engineer, Tractebel offers its competencies and services to nuclear new build projects, nuclear power plant operators, research centers, nuclear waste management agencies.
- The Group Nuclear Safety Department is in charge of defining and overseeing the implementation of the Safety related policies for all nuclear activities of the ENGIE group
- The ENGIE Nuclear Development Division (NDD) is in charge of the development of Nuclear New Build (NNB) Projects, and has a governance role concerning the strategic vision, talent management, research & innovation, expertise in nuclear technologies, knowledge management for the nuclear activities for the ENGIE Group. The NDD is also in charge of the global nuclear training programs for the ENGIE Group.

2. Status of the Nuclear Education in Belgium and needs of the Group

In the 1990's, the academic education in nuclear engineering in Belgium – both in the Flemish and the French community – consisted of one year of post-graduate studies complementary to the civil engineering degree . On the Flemish side, this sixth year of studies was organised by two universities – Universities of Gent (U-Gent) and Leuven (KUL). In the French community it was organised by four Universities: ULB (Brussels), UCL (Louvain-La-Neuve), ULG (Liège) and FPMs (Mons). All of them prepared the graduates for a career in electricity production, technical consultancy and research.

Despite many efforts taken, the recruitment of new students seemed to be a difficult task at that time. The reasons for this are multiple. First of all there was the negative influence of the public opinion towards nuclear energy as a consequence of the Chernobyl accident. Secondly, there was the uncertainty regarding the phase out of nuclear energy in the long term. Furthermore, from the side of the operators the lack of innovative projects failed to attract the students. Because of the educational decrees, which demand a minimum number of students, it became difficult to maintain these two programs.

In 2002 the Belgian Universities involved in the former programs decided to create the post-graduate BNEN programme, the Belgian Nuclear higher Education Network, in close collaboration with and financial support of research centres, the nuclear industry and other stakeholders. Its primary objective was, and still is, to educate young engineers in nuclear engineering and applications as well as to maintain and develop high level nuclear engineering competences in the country. During the preparation of the BNEN programme all partners agreed to strive for top quality goals. BNEN is linked with university research, benefits from the human resources and infrastructure of SCK•CEN and is encouraged and supported by the partners of the nuclear sector. (*Academic Education (and Training) in Nuclear Sciences in Belgium* Th. Berkvens, M. Coeck, P. Baeten SCK•CEN, Boeretang 200, BE-2400 Mol, Belgium, in Revue des Questions Scientifiques, 2013))

ENGIE is a major sponsor of this program and a significant part of the BNEN graduates is employed by the Group. But it is not sufficient to meet the needs of the Group.

Indeed, the needs of the Group are rather large: the impressive nuclear industrial development in Belgium that has known its apogee in the ‘60ies and ‘70ies had been accompanied by extensive recruitments. But during the following years, with the cessation and moratorium in Belgium on any of the new builds, the recruitment of young engineers has drastically decreased, resulting in an unbalanced age pyramid. Nowadays, with the retirement of the pioneers and baby boomer generation on one hand and the new perspectives for long term operation and new builds, the needs in young engineers are huge. The Nuclear Trainees Program has been created to compensate the imbalance between the offer from the schools and these needs of the Group.

3. Nuclear Trainees program in ENGIE: Organization and participants

3.1. Participants

The trainee - participants are coming from divers ENGIE entities from all over Europe.
They are all junior engineers

- with a degree in engineering (Bac +5)
- with less than 3 years of working experience
- with a very good knowledge of English
- who are mobile and/or willing to go to other countries all around the world.

Every entity has a dedicated person (SPOC-Single Point of Contact) who takes care of each trainee (integration in the entity, follow up of the learning results, taking action in case of any problems).

3.2. Trainers

The trainers are either part of the ENGIE staff or are working for training providers. They are selected by a committee for their technical knowledge and pedagogical skills. A content committee controls the consistency of the content for all modules and guarantees that the training objectives are met. An annual meeting is held with all trainers to give them an overview on eventual changes in the content and to discuss further improvements in the pedagogical approach and the training content.
At the end of each module trainees will be requested to give their written feedback, which will be taken into account for any improvements needed for the module.

3.3. Organization

The one-year training program runs once a year, with 65 participants on the average. One week per month is dedicated to training programs, the rest of the month the trainees are working on-site.

4. Nuclear Trainees Program ENGIE: technical content

4.1. Courses and visits

The program content, elaborated by the Content Committee, is based on requests from the entities, the requirements of the qualification “G” of the Safety Analysis Report (see below) and the feedback of the trainees. The challenge is to coordinate courses given by a large panel of trainers coming from various horizons whilst covering the whole matter, but avoiding unnecessary repetitions. The Content Committee is in charge of this task.
The technical program consists of:

4.2. Week 1: Health & Safety and radioprotection

This health and safety course covers the Global Health and Safety policies of the Group ENGIE and the responsibilities of the future managers in that field, in particular regarding the prevention of work related accidents. The main message is the safety culture and the role each manager has to play as a safety leader. It is not the objective of this course to get a certificate in health and safety, but to raise awareness about their future role and responsibilities in that field as future managers.
The radioprotection course gives the basis of radiation physics, their interaction with the matter, how to measure them, the biological risks, and how to protect workers. This training

is given by Controlatom and is consistent with the legal requirement according to the Royal Decree of July 20th, 2001 in Belgium and Art. R231-289 in France. The objective is to give trainees access to the Nuclear Installation thanks to the certificate that is delivered at the end of this course.
The week ends with an exercise at the school workshop on the nuclear site of Tihange.

4.3. Weeks 2 and 3; Nuclear fundamentals and preparation courses

These 2 weeks are given at the Belgian Research Center (SCK.CEN) in Mol. The covered matters are the following ones:

- Day 1: Physics of radioactivity and radiation physics
- Day 2: reactor physics and neutronics
- Day 3: reactor dynamics and control
- Day 4 and 5 : Main reactor lines and exercise on the BR-1 reactor
- Day 6: Material issues: mechanical tests and stress corrosion cracking
- Day 7: Material issues in nuclear fuel and cladding followed by a visit of hot labs and corrosion labs
- Day 8 and 9: reactor thermal-hydraulics
- Day 10: visit of the underground laboratory (final disposal solution in clay layer)

These courses are given by researchers from the research centre. The level of details is aimed at giving the trainees the main theoretical basis in the main nuclear sciences.
However, considering that for most of the trainees these notions are completely new, preparation courses are given by colleagues from Tractebel and Laborelec. These preparation courses last 3 days and cover a preparation to neutronics, to thermodynamics and to metallurgy.

4.4. Week 4: PWR

This course is aimed at describing the Pressurized Water Reactor, its main components and its main auxiliary systems and gives the basic principles of the normal operation of the PWR.
The whole week is shared between theoretical presentations and exercises on a compact simulator. Each team operates a PWR from cold shutdown to full power and back to cold shutdown.

4.5. Week 5: Nuclear safety

After a few reminders of the PWR, the safety principles are explained and the application of the defence in depth to the design of the plant: multiple barriers, safeguards systems, ….
The condition 2 and 3 accidents are then presented with detail on some examples, followed by the accidents from external origins and consequences of Fukushima accident on the designs. A presentation of TMI accident introduces the severe accidents, the Tchernobyl accident is exploited to develop the safety culture. Quality management and technical specifications are then presented, and the week ends with the crisis management, nuclear security and the human performance tools.
Each day is completed by individual exercises based on an e-learning tool called “the life of Electra” that presents, with additional details, the matter seen during the day.

4.6. Week 6: Fuel cycle, Waste and decommissioning

This course covers the whole fuel cycle: starting from mining activities, the conversion, the enrichment processes, the fuel fabrication processes, the evolution of the fuel in the core and the in-core fuel management. Regarding the back end, the closed cycle option is presented here: reprocessing, MOX design, fabrication and recycling, and enriched reprocessed U purification and recycling.
The waste course is presented by an external consultant. The training presents the various sources of nuclear waste from operation and reprocessing, the treatment of the effluents up to the obtaining of solid waste, the conditioning and storage of the waste and their final disposal.
This course is completed by a visit of the BELGOPROCESS plant.

4.7. Week 7: Maintenance

The objective of this course is to show the major link between maintenance and nuclear safety, since a low quality maintenance can cause shutdowns, leaks, it can induce latent errors and risks, and make safety systems unreliable.
The course addresses the maintenance methods and plan, an introduction to AP-913, Failure Modes, Effects and Criticality Analysis (FMECA) and reliability centered maintenance (RCM), and the main tools like root cause analysis (RCA) and Failure Reporting, Analysis and Corrective Action System (FRACAS).
The week ends with a visit of one NPP, and in particular the fuel handling tools.

4.8. Questionnaires: training and exams

More than 2000 questions have been created on a training platform. A selection is used for the tests presented at the end of each module and the exams or post-test at the end of the program.
Before the first course a pre-test is given which gives an insight about the knowledge level of the trainees. For the trainees this test gives them useful information about the expected knowledge level at the end of their trainee program.
After each training session the trainees are asked to complete to measure their comprehension of the attended course. This will also measure the capability of the trainer to teach the concerned matter in an appropriate way. Results are transmitted to the SPOCs and to the trainees.
At the end of the trainee program participants will have to take a final test on all matters presented which will be qualifying.
All the questions are of multiple choice type and are stored on an internet platform that allows easy management of the questionnaires and their corrections. That same platform is at the trainee's disposal for training, which allows to follow their daily activity by the platform manager.

5. Nuclear Trainees program in ENGIE: non technical content

5.1. Boarding Days

The Boarding Days are a first induction program to the ENGIE group and it's nuclear activities as well as to the Trainee program itself. It gives a first insight into the nuclear value chain of the group, participants have the opportunity to meet the CEO's of the different nuclear entities, to network amongst themselves as well as to visit the Tihange NPP.

5.2. Global meetings

The Global meetings are the occasion twice a year for participants to meet again all other trainees from their track in order to discuss developments in the nuclear sector, strategic orientations of the ENGIE group in nuclear or R&D topics related to nuclear, network again and meet Senior Managers of ENGIE.

5.3. Personal development

A first input on Leadership skills is given through a 5 days module on Leadership and Presentation skills. Participants will discover their personal preferences and Leadership style, learn how to have more impact and influence and get equipped with a better understanding of team management challenges. This training is very much oriented towards an experiential learning approach which combines some theoretical input with a lot of simulations. The learning acquired in a very practical presentation skills module have to be applied to a final non-technical presentation at the end of this module.

5.4. Final meeting

After a successful completion of the NTP Junior program participants will receive their diploma from Senior Managers of the ENGIE group during the final meeting, usually held in Paris.

5.5. Networking

Most courses are residential: full weeks lived together in the same place develop close contacts between the trainees and create a network that will help them all along their career in the Group, and even out of the Group. As a young engineer, occupied in a multidisciplinary project, what is better than knowing other young colleagues to establish the link with the right competences from other departments?

It's always been our aim that our trainees get a group of friends who, in twenty years, always have in mind to have lived this program, who, mainly will have sustained contacts throughout the Group.

In order to create strong bonding, the groups are mixed and differ from one course to the other with the objective of giving all the trainees the opportunity to meet all the other trainees of his session at least for one week during the year. That is a challenge for the planning manager, and requires a perfect respect of the program by all the participants.

Various communities are created on the internal website to promote this networking out of the residential courses: each session has his own community since last year, alumnis are also invited to join the Alumni community. These communities work on the same principle as the public social networks: the participants are asked to share their professional experiences and good practices, regarding the courses, the exercises, but also their day to day work.

5.6. Chart

The Group offers its employees a safe and good work environment, in which they are able to feel recognised and respected. The Group also aims to provide opportunities both for career and personal development.

In the framework of this commitment, the ENGIE Group offers the junior engineer the opportunity to follow the Nuclear Trainees Program (NTP-J).

Most of the time it is quite challenging for the trainees to follow at once this demanding education program and their day to day job, since they are young professionals who already have their activities within technical teams. Therefore, as a counter part to the commitment of the Group, the trainees and their hierarchy commit themselves to give total priority to the courses and they are asked to sign the following agreement:

As an employee of ENGIE and as NTP-J trainee, you agree to:

- *follow the program for its entire duration, i.e. to attend theoretical and practical courses, site visits and to participate to events organized by the NDD ;*
- *arrive on time to training and attend classes until the end, review included. Lessons are generally from Monday 8.30 AM to Friday 5.30 PM ;*
- *participate and make collective/individual work requested by the teachers outside training hours ;*
- *respect the internal rules of the hosting facilities (business, hotel, training, industrial site, …) and to have at all times an adequate behavior (including the respect of dress code) ;*
- *behave courteously with all stakeholders and all other participants of the program ;*
- *comply at all times with laws and regulations (labour, compliance, …)*

Thanks to the NTP-J, you will improve your nuclear technical skills but also behavioural and job-related skills. In addition, the program will enable you to build up an extensive network of contacts among players in the nuclear field inside and outside the Group.

Given the scope of the training, the value of its content and the image of the Group that it promotes, the Group expects you to show commitment, motivation and punctuality, both in the training modules and at events organised in connection with the program.

Finally, keep in mind that the results of the technical evaluation made during your one year Traineeship will be taken into account in the annual assessment of your personal objectives.

5.7. Degree of retention

Along the first 5 years after their training, about 6% of the young engineers leave the ENGIE Group. Most of the time, they move to other nuclear companies where the training they received in our Group is a plus for them and their new employer.

In this context the benefits of Nuclear Talent management have to be seen, focusing on talent retention by diversifying the nuclear career tracks.

5.8. Accreditation by BSA

Referring to the various international rules related to the "qualification and training of personnel of Nuclear Power Plants", the Safety Analysis report of the Belgian Plants specifies the level of qualification required for the employees according to their job role. In particular, qualification G requires a university degree in nuclear science from a Belgian or foreign university or a degree from courses of basic nuclear science provided by a university, a school of specialized industrial engineers, or a nuclear science institute.
Courses related to this basic training must cover at least the following subjects:

- Reactor Physics
- Reactor Control
- Ionizing radiation
- Nuclear instrumentation

The duration of this training should be a minimum of 120 hours
The Nuclear Trainees Program has been presented to the Belgian Safety Authorities and has been recognized as fulfilling the criteria for the "G" qualification. Hence recognized degree can be delivered to the Trainees who have passed the final tets of the program.

6. Conclusion

"Combining practical training and courses on different sites allows to totally embrace all the nuclear specialties. It is also the ideal way to make contacts within the Group. We will spend a lot of time together and this will allow us to learn well working as a team. " (Inge, former NTPJ participant).
As a conclusion it can be noted that the NTP Junior program is a widely recognised program as well inside the ENGIE group as well as outside. The high number of applications to the hiring entities in order to become a participant of a new track testifies as well of the attraction of this nuclear training. For the ENGIE group, despite the investment costs for such a program, the 10 years of existence of the NTP Junior program have proven it to be a very efficient tool in the replacement of the retiring nuclear white collar workforce as well as in the creation of a nuclear community within the group.
The very good quality of its content and the content delivery is constantly monitored and improved resulting in a qualifying training program that corresponds to the requirements of the Belgian Nuclear Safety Authorities. It prepares young graduates for a successful career as a nuclear engineer inside or outside the ENGIE group in providing them with a sound theoretical knowledge, very practical application of this knowledge and a good network in the nuclear community. Being part of the program is a big challenge for all participants, but also a great experience. For the ENGIE group the return on investment of the program has been proven to be very positive and effective in the preparation of its future nuclear workforce.

HOW DO ORGANIZATIONS BUILD THE LEADERSHIP TEAM'S CAPACITY TO LEAD THE ORGANIZATION AND TO IMPROVE PERFORMANCE?

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Managers @ work: How do leaders support mental fitness of employees in a changing business environment (the German AREVA way)

Why „mental fitness"?

Psychic (mental) burden/overload is defined as „the body of all ascertainable effects which extrinsically come up to an individual and impact him/her in a psychic manner". [source: DIN EN ISO 10075, Ergonomische Grundlagen bezüglich psychischer Arbeitsbelastungen]
The norm DIN EN ISO 10075 does not focus on any kind of personal psychic deficit of an individual but on the burden/overload of mind and soul.

The norm DIN EN ISO 10075 demonstrates that dealing with psychosocial risk is much more than "avoiding malpractice". Other standards complement examples what is meant by psychosocial risks. [OHSAS 18002:2008 - Arbeits- und Gesundheitsschutz-Managementsysteme – Leitfaden für die Implementierung von OHSAS 18001:2007]

Results of a Bavarian study highlight that psychic conditions raised by 15% within the last decade. Reasons for this increase are incremental squeeze (need for more performance) and emotional fatigue based on lasting concern about employability, job security and the relevant economic climate. [source: TKK Techniker Krankenkasse]

Psychosocial burden is one of the most relevant job-related burdens and is identified as no. 4 (with the visible potential to become part of Top 3-ranking!) of all reasons that lead to absenteeism. [source: BKK-Gesundheitsreport Deutschland]

Who is in the driver seat?

To prevent PSR Psychosocial Risks and to support mental health and fitness the role of different stakeholders will be addressed:

Organizational factors that impact organizational health as well as individual health

	Employee	Colleague	Manager n+1	Manager n+x	HR	HSQE	Social service	Medical service	Works council
Psychological Support	X	X	X		X		X		X
Organizational Culture	X	X	X	X	X	X			
Clear Leadership & Expectations	X	X	X	X					
Civility & Respect	X	X	X	X	X				
Psychological Job Fit			X		X				
Growth & Development	X	X	X	X	X				
Recognition & Reward		X	X	X	X				X
Involvement & Influence			X		X				X
Workload Management	X	X	X	X					
Engagement	X	X	X	X					
Balance (esp. work-private-balance)	X		X						
Psychosocial protection	X	X	X				X		
Protection of Physical Safety	X	X	X		X	X		X	

This matrix shows that in a company a lot of different people are involved and working in avoiding Psychosocial Risks and all these actions prevent PSR cases and support mental health and fitness.

The table also shows, that the manager has the most important role and responsibility for the health of his employees and the company. Within every single topic the manager is on the one hand involved and has on the other hand the influence to avoid the risk of Psychosocial Risks for his employees. This is one point why it is that important, that the manager takes time to speak with his employees seriously. Within such dialogues he can get a feeling of the mood, the problems and the fears of the employees and he can use the time to create confidence within his own person, too.

Another very important point in the working area of every employee are the colleagues. Colleagues have very good grasp and see influences and reactions from the employee that allow them to draw conclusions from the employee and how deep he is encumbered. As they have another relationship to the employee than the manager they can easily offer help or talk to the employee about what happened and how to avoid such situations in the future.

Last but not least for sure the employee himself has to care for himself and point his feelings with the first indications of Psychosocial Risks to his manager or another person he trusts in (f.e. Social or Medical service).

What are processes, methods and actions?

To create an environment that supports mental health and fitness AREVA acts on all levels (organization, team, individual) and places targeted interventions as well as actions/processes/tools:

This means we have a very clear organizational competence & behavior within our Value Charta, our vision, mission and the guidelines for our managers (manager@AREVA) and the goals we cascade from the managers to the employees.

A high number of trainings give the possibility to our employees to get support in their daily work and this can help to strengthen their mental fitness.

Within AREVA we consider coaching and mentoring as added value for the development of individual employees and not as an indication of sickness. Our employees are very open minded for coaching and mentoring processes and see this as a chance for learning and developing themselves.

All this interactions were also audited by TÜV Süd and AREVA GmbH won “Deutscher Bildungspreis” 2015 and 2016 in succession.

What are AREVA´s lessons learned?

Strong leadership is the backbone of a transforming organization like AREVA. Our leaders are in the driver seat to support strategy and to execute in a sustainable as well as an appreciative manner. They are the catalysts for attracting and developing people to move the organization forward. "Reduced to the max" the basic skills deal with this leadership challenge, the competences are empathy, clarity and orientation. In other words

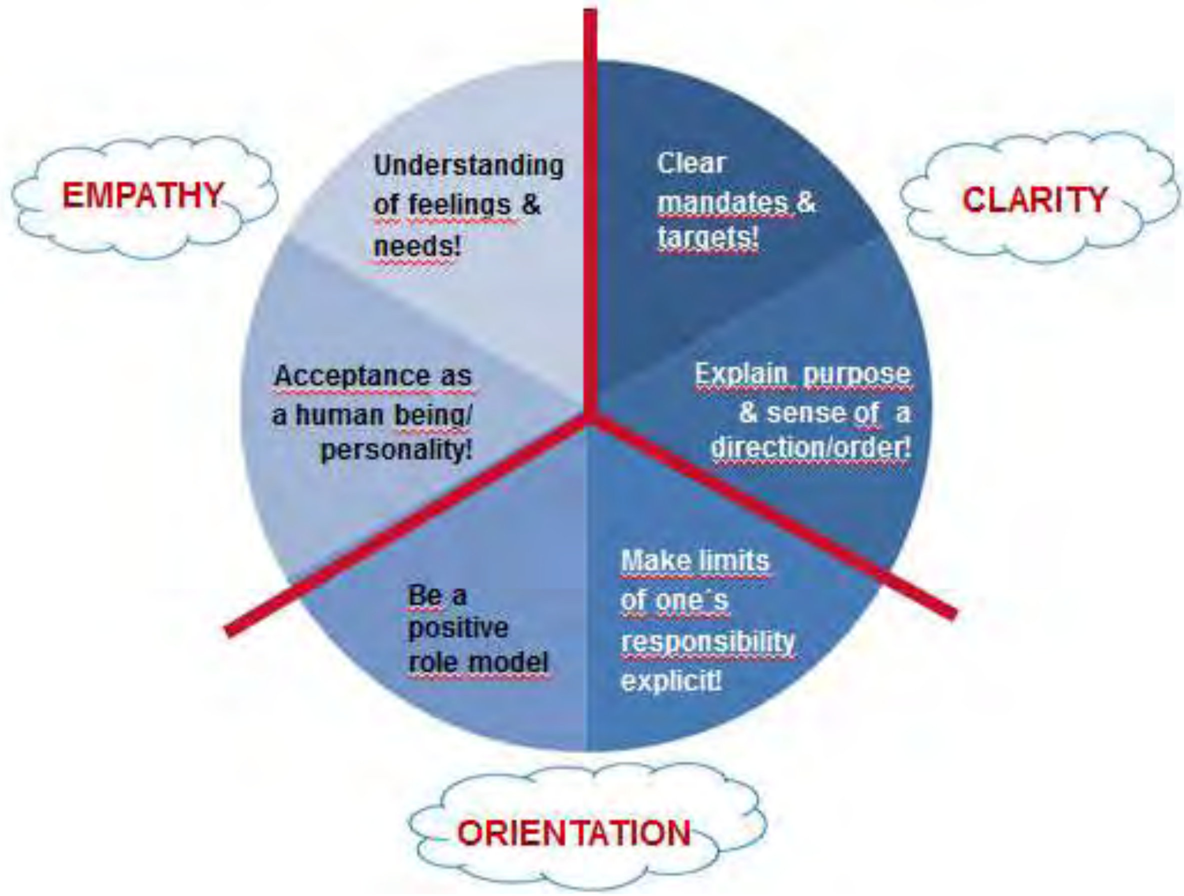
- the ability to communicate appropriately

- the application of appropriate direction and support, and the involvement and valuing of employee input,

- the ability to put others before oneself, to empathize, to seek to understand and build rapport, and to show concern.

Based on our experience from training and inspiring more than 200 disciplinary managers we strongly belief that "Leading by EChO" is the key of being successful as a leader in times of change and transformation.

Due to the taken actions the results (proved by an audit on PSR Psychosocial Riskmanagement) demonstrate that AREVA managers and staff have started to develop their mind-set towards three key-drivers of mental health and mental fitness: empathy, clarity and orientation.



Empathy:

- **Acceptance as a human being/personality:**
  Show your employee that you accept him and want to motivate him, but this does not automatically mean that you must have sympathy for him
- **Understanding of feelings & needs:**
  Respect the feelings & needs of the employee without making them to your own problems

Clarity:

- **Clear mandates & targets:**
  Give clear mandates to your employees without room for misunderstanding and set manageable targets
- **Explain purpose & sense of a direction/order:**
  Use this time to involve your employee in the topic and empower him to find the best solution for this important issue

Orientation:

- **Make limits of one's responsibility explicit:**
  Define the limits of your employees responsibility to empower him for own decisions within this scope
- **Be a positive role model:**
  Act as you want your employees to act, rethink not only of work but also of work-life-balance

RESEARCH BASED EDUCATION AS A NECESSARY INFRASTRUCTURE FOR SUSTAINABLE DEVELOPMENT OF NUCLEAR ENERGY

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ABSTRACT

The paper argues that the nuclear energy may improve the public trust significantly and at the same time improve the already excellent safety record by a much stronger commitment towards the research based education and science based decision making in the industry and the regulatory organizations. This could also help preserving and strengthening research based education, which is a necessary national infrastructure in all countries with nuclear power programme. A good starting point would be to embrace the science and higher education organizations in the corporate nuclear safety cultures through strong partnerships and exchange of staff.

1. Introduction

Access to sufficient, environmentally acceptable and affordable power sources might well be one of the most important and urgent challenges that humankind will have to solve within a few decades.

The electricity from the nuclear fission is abundant and competitive low carbon energy having one of the lowest impacts to the public health and environment [1]. As such, the nuclear energy could immediately provide significant contributions towards the neutralization of the threats caused by the climate changes. This has been made possible through the substantial and long term efforts of the nuclear industry to sustain and improve the safety of the nuclear power plants. These efforts were systematically supported and sometimes also lead by the competent regulatory authorities and academia worldwide, and over the years resulted in unparalleled levels of stability and maturity.

Unfortunately, the dwindling public acceptance has recently become one of the major challenges that face the nuclear industry and sustainability of the nuclear energy. On one hand, it's very low impact on the public health and environment is undoubtedly and thoroughly supported by the available scientific and technical knowledge [2]. On the other hand, the public – especially in the post-industrial societies – does not seem to acknowledge this. Indeed, as far as the questions of nuclear safety are concerned, most of the people in EU trust scientists much more that the regulators, government, media and industry [3].

Yet, both the regulatory authorities and the industry in some countries seem to be progressively losing interest for intense and sustainable cooperation with the higher education and research establishments. Indeed, the already achieved and unquestionable high maturity and stability of the industry and regulators might give rise to a perception that further research cannot bring much added value to the safe operation of the plants and that higher education might be fully substituted by professional training. Such perception may be easily augmented by the economic recession. Ultimately, it might lead to a severe deterioration of the independent nuclear safety related research and higher education, which is considered a fundamental national infrastructure for nuclear safety [4-6]. Examples of cases, where the dwindling independent nuclear safety related research and higher education has been noted, include [7-10]. Examples describing actions being taken to strengthen and intensify the dwindling research and education include [11-14].

Fortunately, we are not yet aware of any nuclear incidents which would be directly caused by the deterioration of research and education. Some possible concerns that might be caused by the deteriorating infrastructures in nuclear and other fields were explored through industrial incidents and accidents, which were caused by the deteriorating infrastructures, including hardware, safety culture and design bases [15]. One of the apparently important observations in [15] is that the deterioration of infrastructures could be associated with the ways how the nuclear stakeholders decide and act, in other words, with the (nuclear) safety culture of the decision makers.

This paper briefly revisits some cases of incidents and accident caused by the deteriorated infrastructures and inadequate safety cultures. Then, some possible and important intrinsic differences in the industrial and academic safety cultures are highlighted, leading to a hypothesis that the nuclear energy may improve the public trust significantly and at the same time improve the safety record by a much stronger commitment towards the research based education and science based decision making in the industry and the regulatory organizations. A good starting point would be to embrace the science and higher education organizations in the corporate safety cultures through strong partnerships and exchange of staff.

2. Examples of deteriorated infrastructure

The deterioration of various infrastructures was undoubtedly at the core of the causal relationships leading to incidents and accidents discussed hereafter. The basic facts are taken from the official reports or published literature. Some degree of interpretation beyond the data given in the reports, or perhaps limited use of anecdotic evidence, have been used for better illustration of the possible causes, consequences and missed potential for avoiding of the infrastructure deterioration. More details are available in [15].

2.1 The Ontario Hydro meltdown in 1997

In 1997, the top management of the Ontario Hydro Nuclear (Canada), one of the largest nuclear power plant operators on the planet with 19 nuclear units at the time, ordered an internal investigation. The team of external auditors, recruited mainly from US utilities was asked to provide “brutally honest” insight in the overall performance of the company. The set of issues under scrutiny included managerial leadership, culture and standards, people and performance, processes and procedures, plant hardware and design, organization and resources and labor relations.

The findings declared the status of the reactor operated by the Ontario Hydro Nuclear as minimally acceptable. The fundamental problems detected included for example “*lack of authoritative and accountable managerial leadership*”, “*the ability to take corrective actions is inhibited by an insufficiently detailed understanding of the standards and practices required to achieve excellence in nuclear operations*” and “*There is no real independent evaluation of proposed operations by people not directly involved in formulating the planned actions*”. The proposed solutions involved for example “*a new approach to the culture, structure, and management” and “a rethinking of employee skill mixes and the regulatory process*”.

Some further interesting citations from the report [16] include:

- “Employees lack a questioning attitude.”
- “Decisions are dominated by a production mentality and managers feel excessive pressure to continue planned evolutions.”
- “At times, personnel cannot comply with the established processes or procedures.”
- “Serious shortages of key management, supervisory and some technical skills exist…
- ”Design basis documentation is not accurately maintained.”
- “The practice of offering critical services, such as training and engineering, on a "fee for service" basis has created an attitude that the groups providing the service are not a part of the team.”

- "The issue of culture is that nuclear tries to keep everything confined within it. [They] won't tell anybody anything. That's not just the Canadian culture, it's the nuclear culture."
- "Good teams can turn bad over 10 years if they're not self-checking and probing."
- "We've been telling you that for a number of years. Over and over again, sir."
- "There's people in management that shouldn't be in management and they don't want to be in management, but it's the only way they can get more money."

As a consequence, seven out of nineteen units were shut down immediately, some of them permanently. The remainder underwent up to two decades of painstaking improvements in hardware and in the culture. More details are available in the report [16].

One could conclude that such events could only be result of a severely deteriorated safety culture, mainly within the middle management, which is the softest form of the essential infrastructure for safe nuclear power. Fortunately, this has been recognized and acted upon by the senior management before the development of any serious incidents.

2.2 Broken rail causing train derailment 2000

Perhaps we should go beyond the "nuclear culture to keep everything confined in nuclear" and look into experience from the non-nuclear industries.

On 17 October 2000 the train traveling from London Kings Cross to Leeds derailed south of Hatfield Station. At the time of derailment, the train was traveling with the velocity between 185 and 188km/h. There were 170 passengers and 12 staff on the train. Four passengers were killed and over seventy were injured, four among them seriously, as the result of the derailment.

The immediate cause of failure was determined as fracture and subsequent fragmentation of the rail. The rail failure was due to the rolling contact fatigue resulting in the presence of multiple fatigue cracks in the rail. The investigations showed that the company in the role of the "infrastructure controller" did not manage properly the maintenance of the tracks. To some extent, the inability to manage the maintenance was caused by the fixed price contracts, which were part of the privatization process in 1994 and could not be influenced by the senior employees of the "infrastructure controller".

Changes in the regulation have been introduced after the investigation to clarify the duties of the "infrastructure controller" and to facilitate the faster investment in the deteriorated infrastructure. More details on the accident investigation and follow-up measures are available in [17].

We should note here that the privatization of the railway system in the UK in the beginning of the 1990's included the splitting of the railway system into infrastructure (tracks, signalization) managed by the "infrastructure controller" and multiple train operators (wheels). Before the incident, the tracks and the wheels were part of the same business unit, and the management of ageing of both wheels and tracks was coordinated within this business unit. Privatization and splitting the wheels and tracks into different business units also disentangled the responsibility for the safety of tracks and wheels into different business units. In addition, the function of the top management of the railway system was dissolved into a set of now competing middle managers (infrastructure, traffic, …) and the regulator should have taken over the efficient management of the competing middle managers. After some incidents and accidents, the one at Hatfield being among the most serious, an efficient regulatory action brought the management of wheels and tracks again under a single control.

In summary, the development of the events was clearly a consequence of deteriorated infrastructures, including the hardware (rails) and safety culture of the decision makers, as well as the designers and managers of the privatisation process and regulators.

2.3 The closure of San Onofre nuclear units in 2013

The steam generators in two nuclear units operated by Southern California Edison were replaced in 2009 and 2010, respectively. Serious vibrations of the steam generator tubes, also resulting in a premature leak after one year of operation, prevented both units from reaching full power after the replacement and finally, through economic analysis, led to permanent shutdown of both units in 2013.

In a recent report by World Nuclear News [18], the US Nuclear Regulatory Commission (NRC) blames the tube vibrations to the faulty design of the replacement steam generators. The faulty design was a consequence of poor documentation of the design changes made in the original steam generators, which were not properly reflected in the plant's documentation including the final safety analysis report. The operator neglected the duty to timely reflect the changes of the plant in the final safety report. This resulted in (1) faulted design bases for the replacement steam generators and (2) in the fact that the design of the new steam generators did not pass the review and approval of the regulator prior to replacement. The regulator on the other hand neglected the duty to oversee if the plant is keeping the design bases in the final safety analysis report up to date. Also, the regulator acknowledged a regulatory oversight leading to the replacement of steam generator without the review and approval from the regulator.

The appropriate regulatory oversight and properly managed design bases can be safely considered a part of essential infrastructures. In the example above, both regulatory oversight and the design bases degraded over time, resulting in a much premature closure of two nuclear power plants and huge economic loss for the operator.

It shall be reiterated here that both infrastructures (design bases, regulator) had to fail at the same time to arrive at the closure of both plants in this case. Proper and systematic oversight would most probably stimulate the operators to keep the design bases up to date. And, accurately updated design bases would certainly enable proper design regardless of the subsequent review and approval by the regulator.

The immediate responsibility probably again goes to the middle management with the operator and regulator for the daily mismanagement of the infrastructural activities. The top management (again with both the operator and regulator) could have prevented the incident by paying proper attention to the management of the infrastructural activities. Both are related to deteriorated safety culture.

2.3 Summary

The following similarities can be found in the above examples:

- Severely deteriorated infrastructures caused rather severe consequences.
- Middle management responsible for the infrastructure was not able to recognize and/or prevent the deterioration.
- Supervisors (top management, regulators) did not provide sufficient resources, access to knowledge and/or adequate supervision.
- The deterioration of the infrastructures, if detected on time, could have been fully prevented with the existing knowledge, e.g. without further research.
- The deterioration of the infrastructure was assisted by deteriorated safety cultures.

3. Interplay of different cultures

The interplay of different cultures that could contribute to the deterioration of safety cultures and therefore also to the development of incidents discussed in the preceding section is illustrated in this section. To this end, the basic concepts of culture and safety culture are briefly introduced, followed by a summary of a recent study outlining possible fundamental psychological obstacles in communicating the scientific facts.

3.1 Culture and Safety Culture

The notion of nuclear safety culture emerged after the accident in Chernobil and has received huge attention in the literature. Indeed, the concept of culture usually includes (nearly) every aspect of the life of an individual in a group and, among others, gives the individuals the much needed sense of stability and predictability. We will rely here on the fairly recent and refreshing discussion on Ethics, risk and safety culture by Kastenberg [19]. He argues that:

(1) *Culture can be defined as the integrated pattern of human behavior that includes thought, speech, action and artifacts on human capacity for learning and transmitting knowledge to succeeding generations.*
(2) *Culture gives rise to a society's values, assumptions and beliefs. Hence culture is concerned with the act of developing the intellectual and moral facilities, especially by education.*
(3) *Culture itself, arises out of a context or paradigm that defines an individual's or a society's cultural conditioning. Hence an individual's or a society's values, ethics and morality are contextually or paradigmatically dependent.*
(4) *For the most part, societal conditioning and the context or paradigm from which it arises is implicit, i.e. cultural conditioning resides in the unconscious (emotive) and sub-conscious (mental). The conscious aspects of cultural conditioning that are cognitive, resides in the mental.*
(5) *Safety culture is "designed" within the larger societal cultural context that is "developed organically". Hence safety culture is affected by the larger culture, usually in an implicit way, as an overlay to achieve a specific goal.*
(6) *When the societal culture runs counter to the demands of safety culture, and is left implicit, it can shift from underlying to undermining.*

The safety culture of every individual is of paramount importance for the timely detection and neutralization of the known and potential threats. At the same time, the safety culture of every individual is deeply influenced by his assumptions, beliefs, education, ability for critical thinking, obedience, etc. These may be also be most heavily influenced by the culture of the society at large.

This seems to be consistent with the words of the Chairman of the Independent Commission reporting to the Diet of Japan after the Fukushima Dai-chi accident, who has put a significant part of the blame for the accident on the Japanese cultural features such as "reflexive obedience, reluctance to question authority, devotion to 'sticking with the program', groupism (collectivism) and insularity" [20].

The interplay between the safety culture and the culture of the society may well be illustrated by the concepts of experience and education. The culture of the society has developed mostly on the experience of numerous preceding generations and only slowly takes on influences from research and education. Safety culture on the other hand has been designed through research and education and progresses rather fast with influences from experience and also further research and education.

As a consequence, there could be many successful safety cultures within a single culture of a society. For example, organizations with different missions tend to develop different corporate cultures. Again, many successful safety cultures might reside within different corporate cultures in a single culture. Let us reiterate that an individual who is typically raised to live in a culture must continuously adapt to the changes in such culture. Similarly, and individual who was educated and trained to perform within a safety or corporate culture, must continuously be educated and trained to adapt to the changes.

Excellent nuclear safety culture might therefore go beyond the active participation of all individuals and organizations involved in the safe utilization of nuclear energy. Learning from experience shall be systematically accompanied with learning from best available scientific knowledge and operational experience.

3.2 Communicating and accepting scientific facts

Many of the facts which are without difficulty accepted by the scientific community may not be accepted as facts by the society at large. Examples include the nuclear power having the lowest impacts on the public health and environment and the threats posed by the climate change on the planet.

A very recent study [21] offered and substantiated a rather simple explanation:

“The “beliefs” individuals form about a societal risk such as climate change are not of a piece; rather they reflect the distinct clusters of inferences that individuals draw as they engage ***information for two distinct ends****: to gain access to the* ***collective knowledge furnished by science****, and to enjoy the* ***sense of identity enabled by membership in a community*** *defined by particular cultural commitments.”*

Now, for individuals it seems quite natural to give clear priority to the beliefs rooted in his or her community or culture rather than to the knowledge he or she acquired from science (and education). In simple terms, the communication between “nuclear” and “non-nuclear” communities or cultures may be easily dominated by the affiliations and beliefs over the scientific facts. Such “communication barrier” is probably among the fundamental causes leading to the conflicts between cultures. In the absence to the evidence about the contrary, we may also assume that similar communication barriers exist between the members of different nuclear safety and/or corporate cultures, e.g. industry, academia, regulators and last, but not least, politicians.

A possible way to overcome such “communication barriers” is to disentangle the affiliations and the scientific facts [21].

5. Conclusions

The incidents and accident discussed above were in general enabled or caused by the interplay of different corporate and safety cultures. As a consequence, certain non-adequate approaches of the management were implicitly or explicitly accepted, regardless of the fact that the risks involved were or could be classified as unacceptable.

In particular, the communication of the available knowledge did not penetrate the groups of peers, e.g., between different levels of management within the company or between different organizations. For example, the management of the “infrastructure controller” involved in the rail accident was aware of the insufficient resources available, but failed to efficiently communicate this to the supervisory level and the regulator. It is noted here that every communication is a two way process, in which both sender and receiver share the responsibility for the success.

It is further noted that the successful communication between members of different communities or cultures may put much stronger trust to the affiliations of communicators than to the scientific relevance of the information. A community or culture, which is more appealing and open to the “nonmembers”, may therefore improve the probability of successfully conveying the message to the members of the cultures, which have not yet assimilated this particular message.

It is reasonable to assume that similar communication barriers exist between nuclear stakeholders and the general public. Similar internal communication barriers, whcih might occasionally prevent efficient sharing of relevant facts between different nuclear stakeholders, is also at the forefront of nuclear incidents discussed above [17, 19] and also much more studied Fukushima Dai-ichi accident [21]. Improvements needed in the internal and external communications might also cause the redesign of the existing nuclear safety cultures and affiliations with them.

A good starting point would be to embrace the science and higher education organizations in the corporate safety cultures through strong partnerships and exchange of staff. This may at the same time improve the communication with the public and the safety records through a much stronger commitment towards the science based decision making in the industry and the regulatory organizations.

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THE EUROPEAN NUCLEAR EDUCATION NETWORK AND ITS ACTIONS IN FAVOUR OF EDUCATION, TRAINING, INFORMATION AND TRANSFER OF EXPERTISE

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ABSTRACT

The European Nuclear Education Network (ENEN) Association is a non-profit organization established by the consortium of the EU 5th Framework Programme (FP) "ENEN" project in 2003. The ENEN Association started as a network of universities and research centers involved in education and training in nuclear engineering in EU countries and is presently involved in the challenging role of coordinating E&T in the nuclear fields in Europe.

The main objective of ENEN is, in fact, the preservation and further development of expertise in the nuclear fields by higher education and training. Its members are now universities, research centers and industrial bodies established in European Countries; in addition, MoUs have been signed with several institutions and networks beyond the borders of European Union, thus reaching th number of more than 60 members.

The objective of this paper is to provide an up to date view of the actions and plans of the Association in pursuing its missions.

1. Introduction

Among the motivations to establish ENEN in 2003, there was the worrying situation created at the time by the lack of attractiveness of nuclear careers in Europe for young generations of engineers, researchers and teachers. Periods of lower popularity of nuclear energy consequent to the occurrence of reactor accidents have several negative consequences on maintaining a stable transfer of knowledge, skills and attitudes (or competencies) in the field. Some reflections on this aspect are reported hereafter.

Public opinion does not recognize or even denies that the risk provided by the whole nuclear fuel cycle is generally well below the one coming from other industrial applications or from daily personal choices, such as the use of own transportation means that are responsible for high yearly death tolls in many European countries. Though it is proven by systematic risk assessment studies, the safety of nuclear reactors results in a possibly too exoteric concept for a common perception of risks and dangers mainly driven by mass media resonance. As a matter of fact the sentence that an "accident anywhere is and accident everywhere" has hardly a counterpart in any industrial application other than the nuclear energy field, making of it a singular subject of discussion that is very difficult to promote in public debates in the lack of a scientifically based attitude.

In such an environment, nuclear industry faces difficulties in expanding and developing with the necessary continuity new products, resulting in phases of market starvation in which it is quite difficult to attract new talents to the nuclear field. The experience of the years before the Fukushima accident, often referred to as "nuclear renaissance", shows instead that when attractiveness is provided by considerable plans for hiring new personnel in industry, also in replacement of retiring professionals, crowds of gifted students enroll in the university courses related to nuclear matters and often achieve optimum results in education and job placement. On the other hand, in those periods it is unavoidably discovered that the capability of universities and training centers to provide the requested manpower has become dramatically lower than the momentary high request, thus creating a rush to "nuclearisation" of non-nuclear educated personnel by "ad-hoc" courses.

This unstable behavior, in which offer and demand of nuclear-competent or nuclear-aware personnel do not match with each other, results in a waste of resources and in a lack of effectiveness in the development of the opportunities offered by nuclear energy. Such oscillations, in fact, sometimes occur with a timing that makes easily offer and demand to be out of phase for a while, with long periods in which the low request of personnel puts at risk the existence of university and training center courses in nuclear matters. By the way, offering courses needs to develop and maintain knowledge, skills and attitudes of teachers, instructors and facilitators, a process whose duration can be measured in decades.

Some recent analyses propose this situation within quite clear contours.

"The nuclear science and engineering community in the EU is beset with numerous challenges that threaten nuclear power's role as a clean and abundant source of reliable energy. These range from growing disinterest in higher education among young and upcoming scientists and engineers to a nuclear workforce that is rapidly ageing and not being replaced. The result is likely to be a lack of future generations to operate, promote and expand the nuclear power sector, as well as the loss of trained experts with the necessary knowledge and technical competencies to build, operate, and decommission current and future nuclear facilities safely." (François WEISS, 2012 Interdisciplinary Study, benefits and limitations of nuclear fission for a low-carbon economy, Topic 4: Education and Training).

The need to maintain and further develop the workforce in the nuclear field is therefore perpetual and might be even stronger, although perhaps less explicit, in the periods of lower public enthusiasm for nuclear energy.

"An extrapolation to 2050 of the '20 % nuclear' scenario indicates that 100-120 units should be built in Europe." (María Teresa DOMÍNGUEZ, 2012 Interdisciplinary Study, benefits and limitations of nuclear fission for a low-carbon economy, Topic 2: SET Plan)

"Even countries that have phase-out policies still have active nuclear programmes associated with generation and ultimately decommissioning." (Gustaf LÖWENHIELM, 2012 Interdisciplinary Study, benefits and limitations of nuclear fission for a low-carbon economy, Topic 3: Research and Development).

The accident occurred at the Fukushima Daichi nuclear power station five years ago is presently causing again a situation of lower enthusiasm for nuclear careers in some countries of Europe, in similarity with what was experienced in 2003 when the ENEN Association was established. Notwithstanding the reassuring conclusions reached by recent reports (e.g., those by WHO and UNSCEAR) about the negligible consequences of the radiological impact from the reactor accident on population health, not even the nearly 20,000 casualties occurred because of the earthquake and the tsunami convince that reactor accidents are often more favourable than natural disasters or other man-made accidents.

While a due global reflection has been already made worldwide to learn from the Fukushima accident the necessary technical lesson in terms of safety culture, it is again for the European Nuclear Education Network the time to be engaged in favour of maintaining competencies in the nuclear field. Good reasons for this action are at least the following:

- it is necessary to maintain in Europe capabilities that can allow competing with the ones of the areas in which nuclear energy is more actively developed, in order not to lose the excellence and competitiveness reached in the past;
- it is necessary to convince about the need of nuclear in the energy mix that will fuel the development in the next decades, especially considering the need for decarbonisation of the energy sector;

- nuclear energy, by the way, is not only nuclear power generation: its vast potential must be then exploited in several sectors (e.g., the medical one) in which education must be preserved;
- it is necessary to try a better coordination of education and training activities in order to promote useful synergies among the fields of nuclear engineering and safety, radiation protection, waste management and geological disposal, as well as nuclear fusion.

Fusion, in particular, requires nowadays competencies developed in the field of fission to complete its process of “nuclearisation”, i.e., bringing laboratory experiments to the industrial scale. In order to create a tighter interaction, an MoU has been signed in February 2015 between ENEN and FuseNet, the network for education in the field of fusion energy, owing to the several interfaces established between the two fields.

Basing on this background, the present paper reports a summary of the activities in which the ENEN Association is presently engaged, highlighting the efforts being spent in in favour of its missions in the post Fukushima era.

2. Own activities of ENEN

Also as a product of previous European Projects, initiatives have been established for promoting mutual recognition and establishing certifications at the MSc and the PhD levels.

Among them, the European Master of Science in Nuclear Engineering (EMSNE) Certification represents an important achievement, which has among others resulted in a remarkable number of Alumni. This certification released by ENEN requires that an engineer graduated with at least 300 ECTS has gone through a curriculum containing at least 60 ECTS of core nuclear matters, including the thesis work, of which at least 20 ECTS have been obtained in a stage abroad at an ENEN institution. This latter feature provides the “European” or “International” character of the studies (international, when the host institution is out of Europe, but connected with ENEN through an MoU).

In 2015 the engineers who have received the certification have been 26. The related Diplomas were awarded during a Ceremony held in the beautiful atmosphere of the IAEA Vienna International Center, as a side event of the 59th IAEA General Conference (Figure 1). For 2016, 29 candidates have been already proclaimed at the General Assembly of ENEN, held in Geel at the Headquarters of JRC-IRMM.

Figure 1. Group picture at the EMSNE Award Ceremony held at IAEA in September 2015

Another relevant own activity of ENEN is the PhD event and prize, whose last edition was celebrated at the International Congress on Advances in Nuclear Power Plants (ICAPP) 2015 in Nice, France, 5-6 May, 2015.

Figure 2. Group picture at the PhD Event held at the ICAPP Conference in May 2015

In this event, doctoral students present their activities and results to a Jury selected among ENEN members and compete for prizes consisting in financial support for dissemination of their activities at major conferences of the nuclear sector. Also this initiative has become a successful tradition and in October 2016 it will be held at the ENC Conference in Warsaw.

3. Ongoing European Projects

The coordination of and the participation in several EU projects represented milestones in the activity of ENEN, allowing to further promote the involvement of its Members in favor of common missions. By the way, the tight interaction with European institutions, led to the recognition of the value of the Association by the European Council in 2008 and to the participation in a hearing of a European Parliament Commission related the new "safety directive" in 2014.

The presently ongoing projects span over a range of challenging activities which qualify more and more the Association in its service to European citizens.

NUSHARE

NUSHARE is a FP7 project implementing a European Education, Training and Information initiative proposed by the cabinets of the Commissioner for Research and Innovation and of the Commissioner for Energy after the Great East Japan Earthquake and Tsunami on 11 March 2011 (Fukushima). Its main objective is to develop and implement education, training and information programmes strengthening the competences required for achieving excellence in nuclear safety culture. Three main target groups have been identified, for which specific courses have been developed: TG1) Policy decision makers and opinion leaders at the level of governments, parliaments, international organisations, scientific communities, journalists; TG2) Staff members of Nuclear Regulatory Authorities and Technical Safety Organisations (TSOs); TG3) Electric utilities, systems suppliers, and providers of nuclear services at the level of responsible personnel, in particular managers.

The recent involvement in the project of the European Nuclear Society, of INBex and of the World Federation of Science Journalists is bringing more momentum to the ongoing actions, initially carried out only by CEA-INSTN, ENSTTI, Universidad Politecnica de Madrid, Tecnatom and ISaR, under the Coordination of ENEN.

Figure 3. Roll-up collecting the logos of ongoing ENEN activities and projects

ENEN RU-II

This project, coordinated by ENEN, is the ideal continuation of the ENEN RU project, which was held in past years, and has the purpose to build on the results achieved at the time to set up joint Education and Training courses with Russian institutions, namely CICET and MEPhI-NRNU. The project is gathering the interest of participants and useful exchanges have been already performed or are being planned. In addition MoUs for student exchanges are being signed by the involved Universities.

PETRUS-III

It is a project coordinated by the Université de Lorraine whose objective is to promote Education and Training (E&T) in the field of geological disposal of radioactive waste. The role of ENEN in the project is to support the development of certifications applicable in the field of geological disposal, also making use of the experience gained with EMSNE, and to provide long term sustainability to the PETRUS Consortium, which will be hosted within the Association to find a legal frame in which its actions can continue in the future.

In addition to the above projects approved under FP7, ENEN is also participating or coordinating two new Horizon 2020 projects.

CORONA-II

This project, coordinated by the Kozloduy NPP, is aimed to enhance the safety of VVER nuclear installations through further improvement of the training capabilities necessary for building up the required personnel competencies. The role of ENEN in this frame will be to provide sustainability to the related training academy in the long term.

ANNETTE
This project (Advanced Networking for Nuclear Education and Training and Transfer of Expertise), coordinated by ENEN, is aimed at promoting a better level of coordination among the different actors in the nuclear Education and Training fields. As it can be noted in Figure 4, the coordination work package represents the major action under which the project will be conducted, while it adhered to the explicit suggestion of the Euratom call to prepare courses for Continuous Professional Development in the frame of a "Master" and of Summer Schools. The project was launched recently and the initial attention to the development of new courses was integrated by a specific attention to the adoption of e-learning tools, considering also the possibility to prepare Massive Open Online Courses (MOOCs) in nuclear matters. Transfer of expertise will be performed not only by setting up the courses, but also by preparing textbooks and/or multimedia (generational transfer) and planning personnel exchanges in industry in different countries (cross-border transfer). Education and Training and Information actions are also included, specifically concerning nuclear safety culture, to provide support and further development to the actions going on within the NUSHARE project.

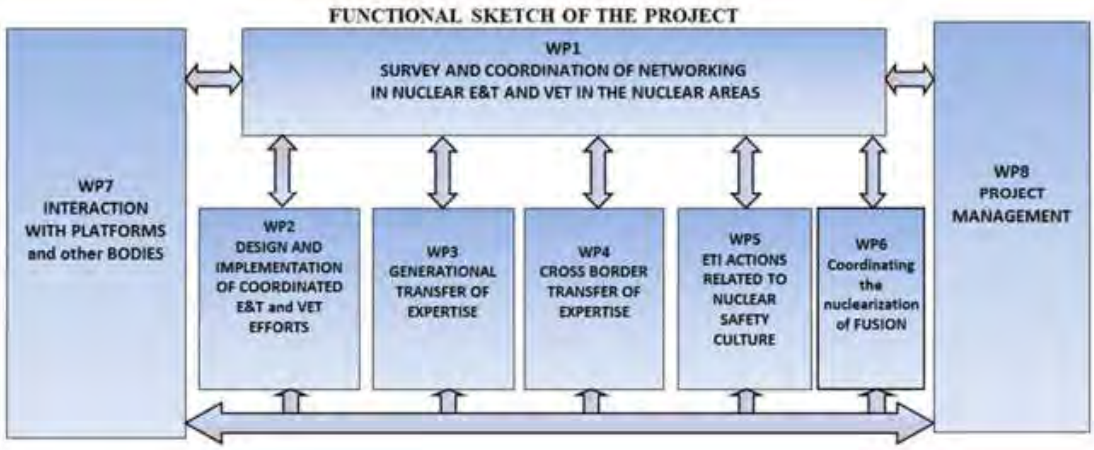

Figure 4. Work packages in the ANNETTE Project

As it can be noted, WP6 relates to the mentioned "nuclearisation" of fusion, involving the proposal of courses in which the engineering competencies from the field of fission can be usefully integrated in the ongoing development of fusion machines. All the actions are aimed to be developed in strict cooperation with stakeholders and end-users, being the technological platforms and the other bodies interested in the development of courses, course material and coordination activities in E&T.

EACEA EUJEP 2
The EUJEP project is financed by EACEA and allows for exchanges of students and teachers between ENEN Members and a group of Universities (TokyoTech and Fukui and Kyoto Universities), together with JAEA. This project represents a very good opportunity for students of both sides to enrich their culture about different geographical areas and spend a fruitful period of study and research abroad.

4. A new level and new roles

New level in coordination
With the participation in the presently ongoing projects, the European Nuclear Education Network is achieving a new level in its service in the fields of nuclear education and training. Proposing coordination in the frame of ANNETTE represents a major step; several times the need was felt to avoid gaps and superposition in nuclear E&T activities led by neighboring working groups and the present initiative, born after checking the availability to join or support ENEN in this effort by the most important actors in the field, will try to achieve a better tightness and harmonization.

Better connection between course providers and stakeholders
The worth of ANNETTE will be also in the attempt to deepen the dialogue between course providers (e.g., academia and research centers) and stakeholders (e.g., industry and platforms). Though the availability of a rather comprehensive offer of courses has been already considered at the time of preparing the proposal, for necessary realism in setting up the Consortium, this offer may be adapted in its detailed learning outcomes in an open dialogue with stakeholders. It is expected that this renewed cooperation will be profitable for developing the content of planned courses and also for establishing a systematic channel of exchanges that will suggest joint actions and better coordinated efforts in the future. In this regard, ANNETTE will be a workbench for establishing these improved contacts between course providers and stakeholders that is expected to make emerging all the challenges and the opportunities involved in this endeavor.

Long term sustainability of European projects
One of the roles of ENEN emerged in different ongoing and concluded projects is to offer long term sustainability to actions that would otherwise remain unexploited after project completion. It is the case, for instance, of the TRASNUSAFE project, aimed to design, develop and validate training schemes on nuclear safety culture for professionals operating at a high level of managerial responsibility in the industrial and the medical sectors, whose courses are being now inherited by ENEN. A specific MoU has been signed between ENEN and the TRASNUSAFE consortium in this regard, in order to leave to the Association the job of yearly advertising and organizing the courses, through a specific Working Group.

Similarly, also the actions planned within the PETRUS-III and the CORONA-II project represent attempts to provide sustainability to projects that will have a long term wake for their useful products. ENEN can play this role of becoming the home for such initiatives.

Transnational certifications
In similarity with the role played through the EMSNE, ENEN can host or facilitate the development of transnational certifications that can be released to different categories of professionals to testify for the acquisitions of knowledge, skills and competencies. This can be achieved by the involvement within ENEN of groups of experts that will recognize the acquisition of the related credits (in agreement with the ECVET system, in particular) according to specific bylaws. Discussions occurred in recent times showed a strong interest for this kind of certifications that, being initially released just on the basis of common agreement, might later become a standard. Though these actions represent clear challenges, it must be recognized that similar processes are already going on in EU projects and that there is already a realistic basis for proposing them.

5. Conclusions

The European Nuclear Education Network is nowadays the result of 13 years of work performed by its Members and its Staff. The actions described herein testify for the vitality of the Association, even in a difficult period for the studies in the nuclear fields.

By the way, it is exactly in these difficult periods that the worth of the existence of an Association like ENEN is mostly felt: maintaining and developing education and training in the nuclear fields represents an action whose value can be appreciated just when the Association has to perform as a flywheel in preserving the momentum that education and training actions must possess in the long term, in order to avoid loss of competences. The new roles of the Association described in the previous section represent partly achieved objectives, partly challenging ones whose achievement requires a higher level of cooperation within the Association and with stakeholders.

In a nutshell, ENEN represents achievements already in place and provides a platform for many opportunities being vital for the sustainable future of the nuclear power. An example is the long-term consolidation and strengthening of the nuclear E&T activities in the EU and its member countries, which will only succeed through a vigorous support of all nuclear stakeholders.

INTERNATIONAL NUCLEAR MANAGEMENT ACADEMY REQUIREMENTS FOR MASTER'S PROGRAMME IN NUCLEAR TECHNOLOGY MANAGEMENT

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ABSTRACT

The development of any national nuclear energy programme is dependent on the successful development of qualified human resources, through a sustainable nuclear education and training programmes supported by government and industry. Among the broad range of specialists needed for the continued safe and economic utilisation of nuclear technology for peaceful purposes, are a most vital component - managers. The International Nuclear Management Academy (INMA) is an IAEA facilitated collaboration framework in which universities provide master's degree programmes focusing on the management aspect for the nuclear sector. INMA master's programmes in Nuclear Technology Management (NTM) specify a common set of competency requirements that graduates should acquire to prepare them to become competent managers. This paper presents an overview of the INMA collaboration framework and the requirements for partner universities to implement master's programmes in NTM.

1. Introduction

The development of any national nuclear energy programme is dependent on the successful development of qualified human resources, through sustainable nuclear educational and training programmes supported by government and industry. Effective management and decision-making are critical throughout the nuclear technology life cycle in order to achieve and maintain high-levels of safety, cost-effectiveness and organisational performance. Management competencies need to be acquired not only by practical industry-focused training courses and on-the-job learning but also by formal education focused on theory, concepts and academic exercises.

Nuclear sector professionals who will move into managerial positions in the future, or those who are already managers, whether in developed or in developing countries, are expected to acquire appropriate competencies for their positions and this requires both nuclear technology related and managerial competencies. Further, in-house training is very costly and may not be as comprehensive as desired. Ideally, managers in the nuclear sector should acquire most of the necessary competencies before they move into managerial positions and complete their learning soon thereafter.

Nuclear regulators and licensed nuclear organisations recognize the need, interest and benefits of establishing formal educational programmes at master's level to meet this purpose. Further, such programmes need to be of high and consistent quality, to be tailored to address the specifics of the nuclear sector, and to be available part-time and by distance learning or short-format, in order to be accessible to busy nuclear professionals. They should also be available in English to support internationalisation of the nuclear workforce and to meet the needs of developing countries.

The International Nuclear Management Academy (INMA) is an IAEA facilitated collaboration framework in which universities provide master's degree programmes focusing on the management aspect for the nuclear sector. The INMA targets current and future managers working in the nuclear energy sector including power and non-power applications. The programmes equip managers with a broad understanding of the nuclear technology lifecycle and specific managerial knowledge such as nuclear safety, a global perspective, engineering economics, social acceptance, public relations and ethical issues.

The strategic purpose of the INMA is to improve the safety, performance and economics of nuclear technologies by promoting and enabling the availability and accessibility of consistent high quality educational opportunities for nuclear sector managers and improving their management competencies.

2. Collaboration framework

A general overview of the INMA is presented in Figure 1. The IAEA supports collaboration among nuclear engineering and science universities in IAEA Member States to develop a framework for implementing NTM programmes through the INMA initiative. Any Member State can develop an INMA-compliant master's degree programme in NTM at a university or educational institute that is authorized by its government to confer a master's degree. NTM programmes must be designed in compliance with the requirements established by the INMA. In order to have the programme officially recognized by the IAEA as an “INMA-NTM Programme” (i.e. as “INMA-endorsed”), the Member State must request (via official channels) to have the programme assessed through an INMA Peer Review Mission coordinated by the IAEA.

In order to help facilitate INMA-NTM programme implementation, an INMA Member-only online sharing and collaboration forum (hosted on the IAEA Cyber Learning Platform for Network Education and Training, i.e. “CLP4NET”) is maintained by the IAEA allowing INMA Members to archive and share educational materials for INMA-NTM programmes.

Universities, or educational institutes implementing INMA-NTM programmes, with the facilitation and supporting tools offered by IAEA, must meet the common requirements established by the INMA, and to the extent possible, share their experience and resources in implementing INMA-NTM programmes, and contribute in further development of the INMA framework. INMA programmes address a variety of very specific competencies that an individual university or faculty may find difficult to implement. Collaboration among INMA universities on NTM programme implementation is encouraged.

The major stakeholders of the INMA-NTM programme include nuclear regulatory authorities, nuclear power utilities, technical support organisations, nuclear R&D institutes and reactor vendors. They are encouraged to send present or future managers on this programme in order to strengthen and improve their competencies as managers. Employers can also collaborate with universities by providing lecturers with industry experience and/or example case studies, both of which provide opportunities for the students to obtain topical and practical knowledge.

The recognition of “Nuclear Management Professionals” (as a professional designation) is a long term goal of the INMA framework, once the INMA-NTM programmes are implemented in several Member States' universities. The concept is to encourage appropriate national authorities to award the designation of “Nuclear Management Professional” to INMA-NTM programme graduates provided they meet additional criteria such as appropriate nuclear sector work experience in each country.

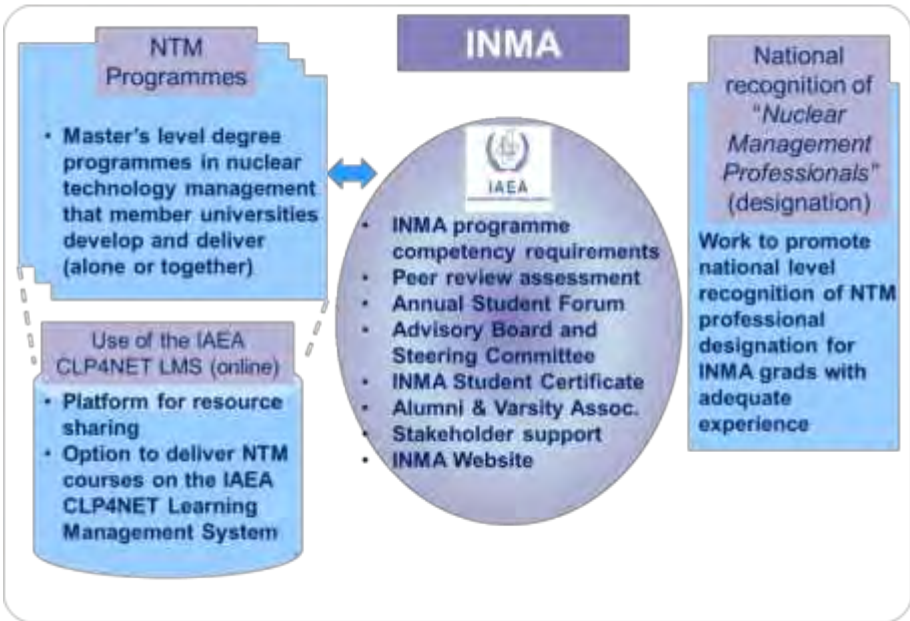

Figure 1. A general description of the INMA framework

Participating universities are required to conclude Cooperation Agreements with the IAEA to establish the basic commitments to the development and implementation of the INMA collaboration framework and their master's programme in NTM. Once the agreement is signed, the university becomes an "INMA Associate Member". When an INMA Associate Member has its NTM programme recognized as an officially INMA-endorsed NTM programme through a formal IAEA-coordinated Peer Review Assessment Mission, the university becomes an "INMA Full Member".

3. Requirements for the INMA NTM programmes

3.1. Competency areas and the minimum levels

The "competency areas" (CA) that professional managers working in the nuclear sector are expected to acquire have been defined for INMA-NTM programmes in an IAEA TECDOC (ref [1]). The INMA-NTM requirements define minimum CA levels that a graduate is expected to achieve upon graduation (refer to table 2 in ref [1] for the details).

The NTM programme CAs are categorized into the four Aspect Groups: External environment, Technology, Management, Leadership. They are listed below with "R" (i.e. required) verses "A" (i.e. "as appropriate") and the minimum level (i.e. 1 to 3) required being indicated in brackets for each. The minimum CA levels range from one to three; "1" means the introductory level, "2" means well-grounded general competency level, and "3" means a high level of competency. The INMA defines only the minimum levels at graduation required for each Competency Area and does not define the level at enrolment, which can be defined by universities as an entrance requirement according to their own programme.

The first Aspect Group, External Environment includes the competencies related to understanding or managing aspects related to the nuclear organisation's external environment such as: political, legal, regulatory, business, and societal environments in which nuclear managers operate. Directly or indirectly, the external environment constrains, orients, influences or governs many of nuclear managers' decisions and actions. Eleven Competency Areas are included and described as below:

(1) Energy production, distribution and markets (A, 1)

(2) International nuclear organisations (A, 1)
(3) National nuclear technology policy, planning and politics (A, 1)
(4) Nuclear standards (A, 1)
(5) Nuclear law (A, 1)
(6) Business law and contract management (R, 1)
(7) Intellectual property (IP) management (A, 1)
(8) Nuclear licensing, licensing basis and regulatory processes (R, 2)
(9) Nuclear security (A, 1)
(10) Nuclear safeguards (A, 1)
(11) Transport of nuclear goods and materials (A, 1)

The second Aspect Group, Technology includes the competencies related to the basics of nuclear technology, engineering, and their application that are directly or indirectly involved in the management of nuclear facilities for power and non-power applications. Fourteen Competency Areas are included and described as below:

(1) Nuclear power plant and other facility design principles (R, 1)
(2) Nuclear power plant/facility operational systems (R, 1)
(3) Nuclear power plant/facility life management (A, 1)
(4) Nuclear facility maintenance processes and programmes (R, 2)
(5) Systems engineering within nuclear facilities (A, 1)
(6) Nuclear safety principles and analysis (R, 2)
(7) Radiological safety and protection (R, 2)
(8) Nuclear reactor physics and reactivity management (A, 1)
(9) Nuclear fuel cycle technologies (A, 1)
(10) Nuclear waste management and disposal (R, 1)
(11) Nuclear power plant/facility decommissioning (R, 1)
(12) Nuclear environmental protection, monitoring and remediation (R, 1)
(13) Nuclear R&D and innovation management (A, 1)
(14) Application of nuclear science (A, 1)

The third Aspect Group, Management includes the competencies related to the challenges and practices of management in the nuclear sector with proper attention to safety and economics. Eighteen Competency Areas are included and described as below:

(1) Nuclear engineering project management (R, 1)
(2) Management systems in nuclear organisations (R, 1)
(3) Management of employee relations in nuclear organisation's (R, 1)
(4) Organisational human resource management and development (R, 2)
(5) Organisational behaviour (R, 1)
(6) Financial management and cost control in nuclear (R, 1)
(7) Information and records management in nuclear (R, 1)
(8) Training and human performance management in nuclear organisations (R, 1)
(9) Performance monitoring and organisation improvement (R, 1)
(10) Nuclear quality assurance programmes (R, 2)
(11) Procurement and supplier management in nuclear organisations (R, 1)
(12) Nuclear safety management, risk-informed decision-making (R, 2)
(13) Nuclear incident management, emergency planning and response (R, 2)
(14) Operating experience feedback and corrective action processes (R, 1)
(15) Nuclear security programme management (A, 1)
(16) Nuclear safety culture (R, 1)
(17) Nuclear events and lessons learned (R, 1)
(18) Nuclear knowledge management (R, 1)

The fourth Aspect Group, leadership requires an understanding of the technology and management of a nuclear facility with due consideration to the external environment in which it operates. Organisational leadership requires vision, strong ethical behaviours, good communication skills with all stakeholders, and a professional disposition in all situations. Leaders in nuclear organisations that have an understanding of high level technological competencies coupled with strong managerial skills are more effective. Four Competency Areas are included in the Leadership Aspect Group and described as below:

(1) Strategic leadership (R, 2)
(2) Ethics and values of a high standard (R, 1)
(3) Communication strategies for leaders in nuclear (R, 1)
(4) Leading change in nuclear organisations (R, 1)

3.2 Learning outcomes

In addition, the definition of each level of CA is in terms of three measurable outcome dimensions of learning: knowledge (K), demonstration (D) and implementation (I), as shown in Table 1. "Knowledge of a subject (K)" requires remembering previously learned material, grasping the concepts and meaning of the material. "Demonstration of the application of knowledge (D)" requires using learning in new and concrete situations, understanding both the content and structure of the material. Knowing "how and when to implement the knowledge (I)" requires formulating new structures from existing knowledge and skills, judging the value of material for a given purpose.

This approach provides sufficient flexibility to enable each programme to be tailored to the needs of local stakeholders and student needs as well as accommodating various programmatic themes (i.e. the extent and level of degree specialisation). Each university may decide how to embed the required CA across the course curricula. Assumptions about CA levels of incoming and outgoing students are stated and the expected learning hours in terms of each K-D-I dimension are considered in course and programme design. The INMA NTM Programme self-assessment tools are provided to map existing courses to CA requirements and to aid in programme design.

Table 1: The definition of each level of CA in terms of Knowledge, Demonstration and Implementation dimensions (from ref [1])

CA Level	*Knowledge*	*Demonstration*	*Implementation*
0	K0	D0	I0
1	K1	D1	I0 – I1
2	K2	D2	I1 – I2
3	K3	D3	I2 – I3

3.3. Learning hours

The expected learning hours needed to achieve each CA level is determined by each university and typically considers prior knowledge and experience. The total learning hours of a NTM programme, if assuming no previously acquired competencies are claimed and/or required for the enrolling students (i.e. students entering at Level 0 for all CA) would be in the range of 3,000 to 4,000 learning hours and is somewhat influenced by local requirements for master's degree programme certification. The total learning hours may be achieved through a combination of taught classes, self-study, Master's thesis/project and industry experience. Fewer learning hours may be required for programmes designed for example for a student cohort required to be entering the programme at Level 1 for many CA.

Table 3 The recommended break-down of the learning hours for the programme by the INMA (from ref [1])

	Aspect Group	Approximate range of learning hours
Courses (Combination of taught classes and/or self-study)	1 External Environment 2 Technology 3 Management 4 Leadership	150 – 450 hours 450 – 750 hours 300 – 750 hours 150 – 300 hours
• Work experience or internship • Master's thesis/ project preparation and evaluation		900 – 1800 hours 300 – 600 hours

Universities can refer to these INMA-NTM common requirements when developing their own NTM programme. These requirements also have an expected level upon graduation which may sometimes be exceeded by universities dependent upon their chosen programmatic theme (i.e. specialisation).

Programmatic themes may include:

- Theme 1: Licensed Nuclear Plants/Facilities
- Theme 2: International New Build Projects (and Refurbishment)
- Theme 3: Nuclear Technology Research, Design & Development
- Theme 4: Decommissioning, Waste Management and Environmental Remediation
- Theme 5: Safety Assessment, Licensing & Regulatory Affairs
- Theme 6: Nuclear Energy Policy, Planning and Programme Development
- Theme 7: Management of the Nuclear Fuel Cycle

Universities can choose to implement one or more programmatic themes listed above or even propose a design for a new programmatic theme. Each university may decide how to embed the required CAs across the course curricula for the chosen programmatic theme(s), as shown in the Figure 2.

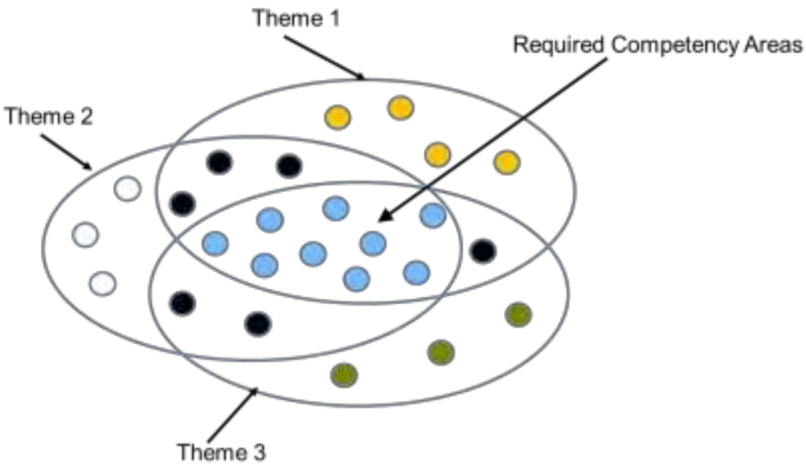

Figure 2 Programmatic themes include “as appropriate” CAs in addition to required CAs

4. Peer review assessment

The INMA Peer Review Assessment is a defined assessment process conducted as an IAEA Peer Review Assessment Mission by the INMA Members with IAEA coordination. The objective of this assessment is to determine whether the implementation of an applicant university's NTM programme adequately realises the INMA programme requirements. Universities have to request the Peer Review Assessment through official channels after concluding the INMA Cooperation Agreement with the IAEA.

The Assessment, which is presented in the form of the Final Peer Review Assessment Report prepared by the Peer Review Mission Team, provides observations and recommendations for possible improvements, based on the INMA Programme requirements and the collective experience and interpretation of the Team Members. Based on a positive recommendation in a Peer Review Assessment Report, the IAEA may grant a university as “INMA Full Member” status and recognize its NTM programme as INMA-endorsed.

5. Conclusion

The International Nuclear Management Academy (INMA) is an IAEA facilitated collaboration framework in which universities provide master’s degree programmes focusing on the management aspect for the nuclear sector. INMA, together with its collaboration framework, requirements and peer review mission have been described in this paper.

To date, the University of Manchester in the UK established an INMA programme in 2014; the National Research Nuclear University MEPhI in the Russian Federation will start its programme in September 2016; Texas A&M University in the USA, North-West University and the University of Witwatersrand in South Africa, The University of Tokyo in Japan, Tsinghua University, Harbin Engineering University and University of South China in China and the University of Ontario Institute of Technology in Canada are considering to start NTM programmes in the near future. Many other universities have expressed interest in establishing their own INMA programmes.

The INMA has been currently supported by the ongoing extra-budget from Japan’s Ministry of Economy, Trade and Industry (METI). An Inter-regional IAEA TC (Technical Cooperation) Project for INMA has been established and inviting other Member States’ extra-budgetary contribution to provide financial assistance to students from developing counties who enrol in INMA programmes. It is expected that over time, the INMA NTM programmes will have a significant positive impact on safety and economics in the nuclear sector by strengthening management competencies and decision-making.

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Up to date training programmes

PLAYING GAMES TO DEVELOP NUCLEAR TEACHING COMPETENCE

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ABSTRACT

Participant-active training of handling transients, ranging from minor perturbations to severe accidents, in nuclear power plants has been developed based on games, simulations, scenarios and role-play. Initially intended for staff at nuclear power plants and the regulator, the concept has been extended to competence development of academic teachers.

1. Introduction – the Swedish BWR Transients Handbook

In Swedish nuclear industry (and in many other countries as well), there is often a gap in teaching material. There are conventional text books used in academic education, whereas at nuclear power plants the relevant information is often in Safety Analysis Reports and similar type of documentation, fit for licensing but not always optimal for teaching.

In Sweden, there is, however, an exception; the *BWR Transients Handbook*, bridging this gap. This handbook has evolved over long time (literally decades) containing some text describing the most important safety systems in general, and their behaviour and use in critical situations in particular. The book contains numerous drawings, figures and tables. If you need a quick overview of all the different plants in the country, this is a very convenient source of information. It is, however, not continuously updated and quality assured, and is therefore not allowed to be used in control rooms.

The BWR Transients Handbook is a compilation of information about the Swedish and Finnish BWR fleet in general, and handling of departure from normal operation in particular. The book contains data from all Nordic units, as well as experience gathered during over 40 years of operation. Moreover, it contains detailed descriptions of significant events in BWRs, many of them less well documented in open literature.

The BWR Transients Handbook is widely used; several hundred persons use it daily in their work in the Nordic nuclear sector, in industry as well as at the regulator. It has unrivaled importance for introductory training of new personnel, and is at the same time used daily by experts with over twenty years of professional experience.

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Presently, the handbook is undergoing the first revision in a decade to take recent modernizations and power uprates into account. This is a joint project in which all Swedish NPPs as well as the regulator collaborate, and the regulator will be the final owner of the material.

2. Training courses on the BWR Transients Handbook

As part of the project to modernize the BWR Transients Handbook, a team has worked on developing courses based on the book. Training courses at three levels have been developed:

Basic. Intended for personnel with 1-2 years professional experience. Basic understanding of the overall design and function of a BWR plant is required. This course consists of two full days, separated by three weeks.

In the first day, the participants work through an accident scenario, in which they need to use the book to get relevant information how to address the issues raised. Presumably, this motivates them to read the book before the second one-day session. This latter session is devoted to whatever issues brought up by the participants. Hence, this second day is never planned, but based on spontaneous teaching.

Mid-level. Intended for personnel with 3-5 years professional experience, and work duties related to safety functions. The basic course or corresponding background is required, as well as basic knowledge of BWR safety systems. This course takes a full week (start Monday lunch, end Friday lunch).

Advanced. Intended for personnel with 10 years professional experience or more, like experienced shift supervisors or leaders in emergency management functions. This course consists of two full days in a row, preferably with overnight stay allowing for social interaction during dinner and thereafter.

Like in the basic course, the participants work through an accident scenario, in which they use the book to get relevant information how to address the issues raised. The challenges are, however, treated much more in depth.

Originally, the primary target group for these courses were not control room personnel. The guiding principle behind the training development is that it should train the people that supports the operators in a difficult situation. Suppose a transient happens in a nuclear power plant, and the control room personnel phones someone with a question like “in our present situation, how long time does it take until the water level is below the upper level of the core?” The person receiving that phone call is in principle the target group of these courses, although in real life these course will be presented also to personnel with less competence to fulfil such a duty.

However, during the development of the training, there have been numerous requests from operations managers to get access to the mid-level and advanced courses. It turns out that much of the conventional training of reactor operators in Sweden today is based on *know-how* with arguably less focus on *know-why*. Much attention is given to procedures and technical knowledge of literally hundreds of plant systems, whereas many operators experience a need for better understanding of the thinking behind these systems and their co-functionality.

3. Teaching methodology

It is well-known that participant-active teaching leads to much better knowledge retention than traditional one-way lecturing (see Figure 1). Therefore, the courses at all three levels are essentially free from traditional lectures. Instead, the courses are almost completely based on games, simulations, scenarios and role-play.

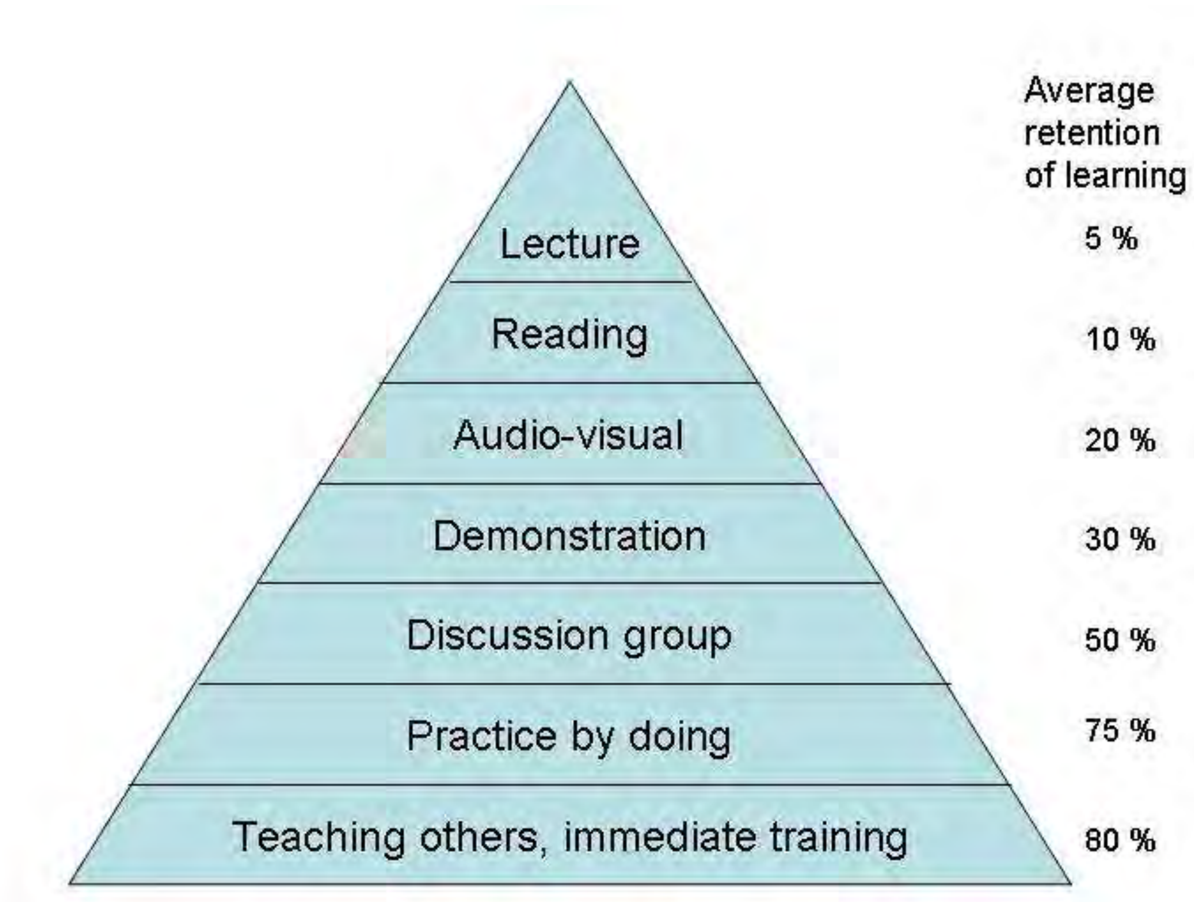

Fig. 1. Knowledge retention for various methods.

Typically, each session of a course begins with a brief introduction to a challenge, i.e., a game, a role-play, a scenario, a case, or some other exercise, after which the trainees work with the challenge anywhere from ten minutes to an hour depending on the challenge. When completed, there is a de-briefing session that can last from a few minutes up to half an hour, in which the participants present their result and the course leaders provides feedback. It is not uncommon that these feedback sessions contain “spontaneous lectures”, motivated by questions from the participants.

Fig. 2. Reflection round, with the course leader (in the middle) and two of the professors deeply involved in how the pressure-suppression principle works in boiling water reactors. Another exercise – classification of accident types – can be seen in the background.

4. Adaptation to academic teachers

Although not initially developed for use in academic education, it has been realized that the material is well suited for competence development of academic teachers. Therefore, we have organized a pilot session in which academic professors spend two intensive days on playing nuclear games.

The material used in this academic course was a subset of all the training modules developed for the three courses above, although the primary source of material was the mid-level course.

The participant experience was evaluated in interviews with the participants, in close connection in time with the actual course. Overall, the participants expressed deep satisfaction both with the content and even more with the methodology. Working together with a realistic challenge, sharing knowledge, followed by a reflection session with the course leader was a highly appreciated environment for competence development. Moreover, the teachers involved testified they will try to use a similar format in their daily teaching from now on.

5. Similar methodology in nuclear business training

Unrelated to the present project, one of us (JB) has been involved in development of the business simulation *Fermi* to train executive decision-making for management teams in nuclear power. The methodology used is very similar; in such a simulation, participants with different skills and backgrounds are composing fictitious management teams of a fictitious nuclear power plant. They are presented with a case describing the state of their plant, and they are challenged by the owners to improve the performance. Initially, the team needs to define a strategy, including a time table, and then a number of challenges occur. A report on a similar methodology was presented at NESTet 2013 [1]. The new simulation will be used during autumn 2016 in a course for regulators from all over EU, aiming at improving the understanding of business aspects in nuclear power safety. Moreover, a number of nuclear power companies have shown interest in using the simulation in competence development.

Learning by doing.

Thomas A. Dewey

6. Conclusions and outlook

Training on handling of transients in boiling-water reactors has been developed, using a participant-active methodology. The present paper has presented an adapted version for competence development of academic teachers. In conclusion, the participants have expressed deep satisfaction with the methodology, and have already started the process to implement similar methodology in their education.

The course package on BWR transients is ready for deployment on a large scale in Swedish nuclear power starting autumn 2016. The same material can be used with minor modifications for any BWR users in Europe. At present, BWR technology is used in Sweden, Finland, Germany, Switzerland and Spain, and there are plans to build BWR plants in the UK.

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ESTABLISHMENT OF TRAINING CENTER FOR VVER TECHNOLOGY

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1. Introduction

Within European Union (EU) there is a strong need for maintenance and preservation of nuclear knowledge and nuclear competence, including VVER competence. Preserving and further developing nuclear competencies, skills and knowledge related to VVER technology is a key factor to the enhancement of safety and performance of nuclear installations.

The wider objective of the project is to implement the Council Conclusions of 5 December 2008 [1] on the future priorities for enhanced European cooperation in vocational education and training (VET) related to skills in the nuclear field. New skills and competences are needed in the context of the Nuclear Renaissance and to fulfil obligations under Article 7 of the COUNCIL DIRECTIVE (EURATOM) for establishing a Community framework for the nuclear safety of nuclear installations [2].

The sustainability of education and training efforts in VVER technology cannot be effective without a permanent structure that assures its follow-up and its survey. The establishment of training center for VVER technology was initiated with the aim to establish state-of-the-art training center accepted by the nuclear industry in Europe and to contribute to the European cooperation as well as to the lifelong learning and transnational mobility amongst VVER operating countries.

2. Projects description and main objectives

CORONA I and II projects are co-financed by the EC Framework Program 7 and EURATOM 2014-2015 Working program of HORIZON 2020.

CORONA I project (2011-2014) “Establishment of a Regional Center of **Co**mpetence for VVE**R** Techn**o**logy and **N**uclear **A**pplications” is based on the development of:

1) Training schemes, programs and materials for VVER nuclear professionals, subcontractors, students and for non-nuclear specialists working in support of nuclear applications as civil engineers, physical protection employees, government employees, secondary school teachers, journalists, etc.

2) Knowledge management portal, which accumulates the available information in VVER area;

3) Specialized regional training centre for supporting VVER customers with theoretical and practical training sessions, training materials and general and special assignment training tools and facilities.

For the CORONA project implementation an eleven-partner strong consortium was established. Below is the list of project partners:

Kozloduy Nuclear Power Plant Plc., Bulgaria - Coordinator
Budapest University of Technology and Economics, Hungary
Fortum, Finland
Institute for Nuclear Research and Nuclear Energy, Bulgaria
EC Joint Research Center – Institute of Energy, EC
Moscow Energetic Physics Institute, Russia
Nuclear Research Centre, Rez, Czech Republic
PM Dimensions GmbH, Austria
Risk Engineering Ltd, Bulgaria
Tecnatom, Spain
Intellectual Technologies Slavutich, Ukraine

The main objectives of the project were:

- Enhancing safety and performance of nuclear installations with VVER technology through specialized initial and continuous training of personnel;
- Keeping the adequate level of safety culture;

- Implementation of European Credit System for Vocational Education and Training (ECVET) principles;
- Preserving and further developing nuclear competencies, skills and knowledge related to VVER technology, as one of the technologies used in the EU.

CORONA II Project (2015-2018) "Enhancement of training capabilities in VVER technology through establishment of VVER training academy" is initiated to proceed with the development of virtual training center called CORONA Academy. This objective will be accomplished through networking between universities, research organisations, regulatory bodies, industry and any other organisations involved in the application of nuclear science, ionising radiation and nuclear safety. Nine organizations from seven countries are involved in the project:

Kozloduy Nuclear Power Plant Plc., Bulgaria - Coordinator
European Nuclear Education Network, France
Tecnatom, Spain
Engineering Support and Intellectual Solutions GmbH, Germany
Risk Engineering Ltd., Bulgaria
Nuclear Research Centre, Rez, Czech Republic
Institute for Nuclear Research and Nuclear Energy, Bulgaria
Moscow Energetic Physics Institute, Russia
Budapest University of Technology and Economics, Hungary

The main objectives of the project are:

- To further develop the VVER training infrastructure;
- To promote the implementation of modern training methodologies and technologies, dissemination of experience and best practices in Europe in the field of training;
- To promote the establishment and development of national training systems for the nuclear power sector in the new members in VVER community (Vietnam, Turkey, Belarus, etc.);
- To contribute to the establishment of a framework for mutual recognition through pilot Implementation of ECVET;
- To integrate VVER education and training with the European education and training in nuclear safety and radiation protection;
- To foster and strengthen the relationship with technology platforms, networks and other organisations in the nuclear education and training sector;
- To promote good practices e.g. remote interactive learning (distance learning and e-learning), leadership academy for safety, etc.

3. Obtained results and planned activities

3.1 Development of training schemes, programs and materials

In the frame of CORONA I project four different target groups were identified and their training needs were analysed in order to develop training schemes and programs, training materials and training tools required to meet the identified needs.

The training schemes were developed for the following target groups:

- Group A: Specialized training on specific VVER technology aspects for nuclear professionals and researchers;
- Group B: Basic training on VVER technology specifics for non-nuclear professionals and subcontractors;
- Group C: Specialized technical training on VVER technology for students studying nuclear disciplines;
- Group D: Safety culture and Soft skills training for nuclear professionals and personnel of nuclear facilities contractors and subcontractors.

The training schemes consist of training programs, set of courses, training materials, training aids and various forms of training activities designed to meet the requirements regarding necessary professional knowledge and skills. The partners participating in the CORONA project have large experience in training of nuclear specialists. The accumulated knowledge in VVER technology and applied practices for training and qualification constitute a solid

basis for unification of existing VVER related training schemes according to IAEA standards and commonly accepted criteria recognized in EU to assure the consistency in education and training programs, courses and training materials between different schemes, target groups and education and training organizations. The training schemes were developed according to the Systematic Approach for Training (SAT).
After the identification of the training schemes the objective was to develop training programs and training materials for the target group as well as to conduct a pilot training. For each target group the following was done:

- Development of training programs and training materials;
- Deliver a pilot training;
- Validate the training program.

The elaborated training programmes cover training courses and units, training settings and the duration of specialized training, ways of control of acquired knowledge and criteria for successfully performed training for the nuclear professionals and researches, non-nuclear professionals and contractors and students.
The training programs collect an extensive number of training materials. The summary of the training programs for four target groups developed within the project is presented below:

- Training programs for group A consists of 3693 training hours (incl. theoretical training, practical training, on-job training and simulator training) in the following areas:
    - Safety Principles of Nuclear Facility
    - Nuclear Facility theory/technology
    - Nuclear Facility Components/ Equipment and Systems
    - Nuclear Facility procedures to perform work
- Training programs for group B consists of 88 training hours in the following areas:
    - Introduction to NPP
    - Radiation Protection
    - Radiation Monitoring
    - Radioactive Waste Management
    - Decommissioning of NPP
    - NPP Safety Concepts
    - Emergency Planning and Emergency Preparedness
- Training programs for group C consists of 177 training hours in the following areas:
    - Safety Principles of Nuclear Facility
    - Nuclear Facility theory/technology
    - Nuclear Facility Components/ Equipment and Systems
    - Nuclear Facility procedures to perform work
- Training programs for group D consists of 101 training hours in the following areas:
    - Organizational culture and safety culture
    - Human performance tools
    - Soft skills
    - Leadership skills

In the course of the project implementation it was decided that Group D – Safety Culture and Soft skills will be embedded into the other three groups.
Evaluation of the training programs was carried out through the pilot courses.
The following pilot courses were conducted as follows:

- Two pilot courses were conducted for group A: Specialized training on specific VVER technology aspects for nuclear professionals and researchers:
    - Pilot Course titled "Certain Aspects of NPP Lifetime Management" organized by the Intellectual Technologies Slavutich, Ukraine and carried out at Kozloduy NPP;
    - Pilot course titled "Training on experimental physics at LR-0 reactor" organized and carried out at Nuclear Research Centre Rez, Czech Republic.

- Pilot course for Group B: Non-nuclear professionals organized by the Institute for Nuclear Research and Nuclear Energy (INRNE) and carried out at INRNE and Kozloduy NPP
- Pilot course for Group C students studying nuclear disciplines titled “Safety aspects of VVER-technologies” organized and carried out in the Moscow Energetic Physics Institute (MEPhI), Russia.
- Pilot course for managers and nuclear professionals titled “Training on safety culture, soft skills and human performance tools” organized by the TECNATOM, Spain and carried out in Loviisa, Finland.

The pilot training results provided an assessment of the training program ability to give specialized knowledge so that the learning outcomes to be applicable to the VVER technology and to be a base for appropriate competence acquiring. The evaluation included recommendations for optimising and improving the training schemes.

Based on this analysis the CORONA II partners elaborated a list of training schemes, programs and courses which should be improved or newly developed in order to make an explicit and comprehensive set of training programs, which cover all areas of training courses necessary for training of the target groups.

One of the conclusions of the evaluations from CORONA I project was that the topic ‘train the trainers’ is not covered by the developed training schemes. The opportunity to ensure that all the trainers have the minimum knowledge about safety culture and have the tools to integrate safety culture as a part of the technical VVER concepts justifies the need to elaborate a new training scheme. The main objective is to cover the theoretical concepts and training skills that the trainers need to have to link the technical concepts to the safety and be aware about how the trainer is a role-model during the training sessions.

Some of the identified new topics and topics that a not fully covered and will be considered for inclusion into the existing training schemes are:

- Spent fuel and radwaste management (not fully covered);
- Deterministic and probabilistic analyses;
- Risk-informed decision making;
- Seismic qualification and seismic risk analysis;
- Assessment of plant residual life time and plant life extension (not fully covered);
- Decommissioning (not-fully covered);
- Special topics for regulatory body training;
- Nuclear security culture – not covered;
- Non-proliferation - not covered;
- Advanced VVER technology introduction – not fully covered;
- Basics course of radiation protection;
- Advanced course of radiation protection in VVER NPPs.

3.2 Implementation of ECVET principles

The European Credit System for Vocational Education and Training (ECVET) is a European instrument that promotes mutual trust, transparency and recognition of competencies and qualifications across the EU Member States. ECVET is based on the description of qualifications in terms of knowledge, skills and competences, organised into units and the allocation of credit points to qualifications and units depending on their relative weight. The technical provisions for evaluation of the individual qualification, according to the ECVET, are units and learning outcomes [3].

The ECVET principles were embedded in the development of an accreditation/certification structure for the training schemes developed in the frame of CORONA I project.

The aim of CORONA II project is to participate in the testing process of ECVET through pilot implementation. The steps which will be taken are:

- Select one particular qualification for pilot implementation, which is subject to increased mobility:
- Define competence requirements for this qualification;

- Select appropriate training scheme for this qualification, based on the defined units of learning outcomes;
- Select two utilities playing the roles of sending and host provider and organization playing the role for competent authority;
- Perform at least one pilot training on selected course;
- Evaluate results and propose corrective measures.

This pilot implementation will support and contribute to the European process of testing of the viability of ECVET idea in nuclear energy industry.

3.3 Excellence Leadership Academy for Safety and Human Factor Simulator

In CORONA I project the safety culture and soft skill training were incorporated as an integral part of training schemes of all target groups (A to C) because the development of a strong safety culture is common for all personnel. Competencies on the “soft” skills for all target groups of: nuclear professionals and researches, non-nuclear professionals and contractors working in the nuclear field and students studying nuclear disciplines or engineering disciplines indirectly connected to nuclear industry, are defined for all related topics.

Based on the evaluation of the results of CORONA I project it was concluded that is necessary to include in CORONA II project new tools as Excellence Leadership Academy for Safety and a Human Factor Simulator, all of them oriented to foster and maintain a strong safety culture. The goal is to create an academy for managers, from field supervisors to chief executive officers, in which they can develop and grow their capabilities as safety leaders and also to have a powerful tool such as Human Factor Simulator for training of plant personnel. Leadership skills and soft skills are also presented at the Human Factor Simulator, as an important factor in relation to safety.

3.4 Knowledge management portal development

The concept of Knowledge Management portal is created to identify, capture, store, organize and preserve nuclear knowledge in VVER area. The Knowledge Management portal will collect information related to the operational experience of VVER reactors, outcomes of scientific research and their application in the nuclear industry, various aspects of the methods implemented, technologies and safety requirements and rules, which will contribute to its wide dissemination and application in various countries, operating that type of reactors. The portal will provide information relevant to the key stakeholders of the nuclear power industry such as scientific organizations, academia, industry and government.

The knowledge management portal which development started within CORONA I project will continuously be built up to include new features and various information for user’s benefit. The structure of the knowledge portal will ensure the possibility of creation, filling-up and further development of the database on available training programmes, training materials, training and methodological documents to be shared by all the countries using VVER technology in the process of nuclear facilities personnel training and advanced training. That will enable the partners to share the materials available in each specific training centre.

The knowledge management portal will be significantly enhanced in order to provide much more information and knowledge resources in an engaging environment, to enable fruitful collaboration amongst all key stakeholders of the VVER community and to support planning, preparation and execution of all key activities of the CORONA project participants.

3.5 Establishment of VVER training Academy

Based on the results of CORONA project it was concluded that the idea for VVER Training Center has a great potential for development and has to be explored further. After a numerous discussions held during the CORONA I project meetings between partners the idea was transformed and enhanced in order to meet the changed requirements in the partners’ vision. As a final result from the CORONA I project fulfilled activities and completed analysis of conducted trainings, as well as taking into account the differences in the conditions due to the legislation systems in the countries applying VVER technologies, the project participants created the idea to transform Training center into a Network of virtual

centers (called CORONA Academy) to offer training for the target groups specialists. Analysis of the training needs and coordination of the virtual centers will be run by administrative office. The administrative office will coordinate the activities and support the collaborations between the training premises of the participating organisations and similar European organisations.
The proposed structure of CORONA Academy is shown in Fig. 1.
Some of the advantages of the proposed structure are as follows:

- Better access to different information materials from different European regions;
- Saving resources for the construction of additional training facilities;
- Benefit from the availability of best trainers in the subject matter;
- Reduction of training expenses;
- Fast access to current information about interested areas;
- Providing opportunity for wider use of training materials prepared within CORONA project.

Establishment of CORONA VVER Training Academy will combine the knowledge and the experience in different fields of the partner organizations and will contribute to the European cooperation and to the preservation and further development of expertise in the nuclear field by higher education and training.

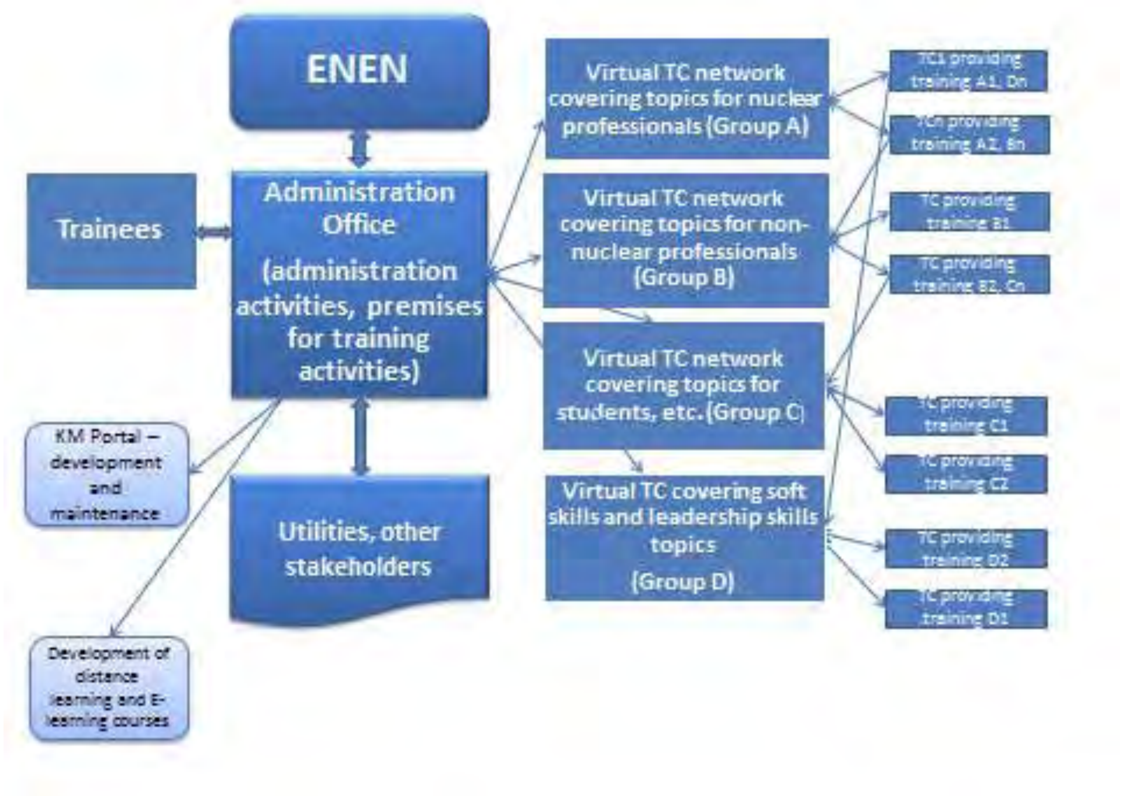

Fig 1. Proposed organizational structure of CORONA Academy

3.6 Conclusion

The CORONA I project was focused on building the VVER competence. Its continuation CORONA II project will aim to maintain and enhance VVER competence through significant improvement of the concept of the training center for VVER technology. This includes, but not only, improvement of the training schemes and training programs, inclusion of new appropriate partners and countries, establishing of VVER training network, inclusion of additional training tools. The project will ensure the development of competences in the VVER area by providing access to the knowledge and best practises available across the world. The specialists from the countries operating VVER reactors will have the possibility to continuously improve their expertise.

With the accomplishment of the planned activities, CORONA II project will provide significant contribution in response to the aims of the EU member countries towards further development of the collaboration between universities, scientific organisations, regulatory bodies, utilities, industry and other organisations applying nuclear science and ionising radiation as a possibility for contribution to the improvement of climate and life conditions by secure, efficiency and safety way.

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[3] Necessary conditions for ECVET implementation, CEDEFOP

CURRICULAR PROGRAMS AND ESTRACURRICULAR ACTIVITIES OF NUCLEAR ENGINEERING EDUCATION AT NATIONAL TSING HUA UNIVERSITY IN TAIWAN

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ABSTRACT

The education in Nuclear Engineering at National Tsing Hua University (NTHU) can be subdivided into 5 areas: 1) reactor physics and shielding, 2) heat transfer and reactor safety, 3) nuclear materials, 4) nuclear science, and 5) beam technology. In addition to course design for students majored in these sub-areas, there are several extracurricular activities aiming at broadening student perspectives about the subject matter and intending to the friendship exchange of students and young researchers in neighboring countries. NTHU has been very actively co-sponsored several regional cooperative nuclear engineering summer schools over the last decade with universities in neighboring countries. Three ongoing summer schools related to nuclear engineering education are: 1) the Nuclear Engineering Summer School co-sponsored with Shanghai Jiao Tong University and Korea Advanced Institute of Science and Technology, 2) the Maintenance Science Summer School initiated and mainly supported by the Japan Society of Maintenology, 3) the Low Carbon Green Energy Summer School co-sponsored with Tsinghua University in Beijing and City University of Hong Kong. NTHU also seek to establish and enhance academic relationships with top research universities in the world. Currently, as strategic partners in nuclear engineering education and research, we have dual master program with Tsinghua University in Beijing and dual PhD program with the University of Liverpool in England. This paper briefly highlights the current status of nuclear engineering education at NTHU.

1. Introduction

Nuclear engineering has a long history at National Tsing Hua University (NTHU), it can be traced back to 1956 when the university was re-established in Taiwan. For the growing needs in nuclear education and research, the construction project of Tsing Hua Open-pool Reactor (THOR) started in 1958. THOR reached its first criticality in 1961. It is a 2 MW, light water moderated and cooled reactor of the TRIGA conversion type. At present, it is the only research reactor in Taiwan, providing stable and intense neutron beams for various applications. The undergraduate program of the Department of Nuclear Engineering at NTHU was established in 1964, while the master program and doctor program were established in 1970 and 1981, respectively. The department has made significant contributions to the development of nuclear power and various radiation applications in the country, in particular cultivating many professional scientists and engineers in this field.

After Three Mile Island accident and Chernobyl disaster, the nuclear industry worldwide had suffered in great depression. The situation also affected the enrollment of the nuclear engineering programs at NTHU in Taiwan. In 1997, the department decided to change its name to the Department of Engineering and System Science (ESS) by expanding its research capabilities into more diversified fields, such as nano-technologies, microelectromechanical systems, and low carbon green energy resources. Still, nuclear engineering remains as one of the important programs in ESS to inspire and train the young generation to become professional nuclear engineers and scientists.

Facing the challenging issues of secure energy supply and the pressure of reducing the emission of greenhouse gases, nuclear power, a stable and non-carbon-emission energy source, has regained wide attention and interest. In the early 21st century, the renaissance of nuclear engineering worldwide also helped us to reestablish the Institute of Nuclear Engineering and Science (NES) at NTHU in 2007. Currently, there are 24 full-time professors in NES including 16 adjunct faculties affiliated with the College of Nuclear Science. The faculty members have various professional specialties in nuclear engineering and science, and can provide complete and high-quality education in nuclear engineering. On top of that, NES also cooperated with several prestigious research institutes in Taiwan and worldwide as well, emphasizing on multidisciplinary education and research in nuclear science and engineering.

2. Curricular programs

The curriculum in nuclear engineering at NTHU can be subdivided into five areas: 1) reactor physics and shielding, 2) heat transfer and reactor safety, 3) nuclear materials, 4) nuclear science, and 5) beam technology. The ESS department and NES institute provide a variety courses related to nuclear engineering and science, attracting many well-qualified students to enroll. For example, for undergraduate students, in the first semester of sophomore year, students can take "*Introduction to Nuclear Engineering*" for an overview of nuclear engineering. In the following second semester, for those who interested in nuclear engineering and would like to learn more in this field are suggested to take "*Principles of Nuclear Engineering*." In this course, fundamental nuclear physics, radiation interaction with matter, and diffusion theory are introduced, covering the content of chapters 1-7 in the popular textbook by J.R. Lamarsh [1]. For junior and senior students in this curriculum, the following courses "*Radiation Safety*", "*Nuclear Power Reactor Safety*", "*Nuclear Power System*", and "*Principles in Photon and Particle Measurements*" are suggested.

On the other hand, NES opens a summer course of "Principle of Nuclear Engineering" for new graduate students who didn't take this course before. In NES, the research development is consistent with the course categories, and is focused on "*nuclear power plant engineering*" and "*nuclear science and radiation application*". A variety of advanced courses are offered in NES to help students learning and pursuing careers in these research areas. For example, NES offers "*Reactor Physics I*", "*Reactor Physics II*", "*Monte Carlo Method*", and "*Radiation Transport Calculations and Applications*" for those students majored in reactor physics and engineering. These courses provide students with the fundamental knowledge and professional skills to facilitate their thesis studies in this field. The teaching and research activities of the faculties are highly organized by the students.

3. Extracurricular activities

In the region of western pacific basin including China, Japan and South Korea, nuclear energy is still considered as an important option for power generation even after the Fukushima nuclear accident. To promote nuclear safety and public acceptance for nuclear energy, it is quite clear that regional cooperative program in nuclear education and experience exchange is crucial to meet these goals. NTHU in Taiwan has been very actively co-sponsored several regional cooperative nuclear engineering summer schools over the last decade with universities in neighboring countries. Currently, the co-sponsors include Tsinghua University (Tsinghua, Beijing, China), Shanghai Jiao Tong University (SJTU, Shanghai, China), Korea Advanced Institute of Science and Technology (KAIST, Daejeon, Korea), Japan Society of Maintainology (JSM), City University of Hong Kong (CityU). Three ongoing summer schools related to nuclear engineering education are introduced as follows.

3.1 **Nuclear engineering summer school**

The first Nuclear Engineering Summer School (NESS) started in 2007 in Shanghai, China, co-sponsored by SJTU, KAIST, and NTHU. Since then, the program has been very successfully held every year in three universities, taking turns as host institutes. It is a one-week workshop designed for senior and graduate students with nuclear engineering major. The number of student participant of the program is about 36, with 12 from each member institute. Typical schedule of the workshop starts with classroom lectures given by professors in the universities during the morning sessions and group project assignments and discussions in the afternoon sessions. Topics in classroom lectures include various aspects of nuclear engineering, such as Reactor Core Design, Nuclear Safety and Accident Analysis, Material Issues, Gen IV Reactors and Innovations. Most of these lectures are at intermediate or advanced levels to strengthen and inspire students learning and creativity.

3.2 **Maintenance science summer school**

This one-week summer school takes place annually, aiming at providing graduate students with the opportunity to learn the practice and theory of maintenance activities in nuclear power plants. It is also intended for friendship linkage of young generation in Asian countries. The 5^{th} Maintenance Science Summer School (MSSS) was held on August 4-8, 2014 at NTHU, organized by NTHU, Taiwan Power Company (TPC), Atomic Energy Council in Taiwan, and JSM. Various lecture courses related to maintenance science and technology were offered, for example, LWR design and safety aspects, potential corrosion issues and anti-corrosion measures, spent fuels of Fukushima Daiichi nuclear power plant after the accident, post-Fukushima safety enhancement and stress test of nuclear power plants, on-line maintenance practices at TPC, etc. There were also technical tours to THOR and Lungmen ABWR nuclear power plant in Taiwan. Total of 27 students from Taiwan, Japan, China, and Korea participated this summer school. The 6^{th} MSSS in 2015 was held in Tokyo Japan, organized by University of Tokyo.

3.3 **Low carbon green energy summer school**

The program started in 2012. It is a three-week event co-sponsored by three universities (NTHU, Tsinghua, and CityU). The classroom lectures cover many introductory aspects in the use of low carbon green energy, including nuclear, solar, clean coal, hydrogen, fuel cell, and energy efficiency and carbon capture. The period of this workshop is relatively long and relaxing, approximately one week activity in each of the three campuses. Local technical and cultural tours are arranged at three host institutes. The number of participating student is around 60, intended for undergraduate students and not restricted to nuclear engineering backgrounds. It aims to provide young generations with insight views on the use of low carbon green energies, such as policy, diversity, security, and sustainability. In summer of 2015, the workshop started from Beijing. During the first week in Beijing, in addition to classroom lectures, there were visits and tours to laboratories in the campus and local research institutes. In the next week in Hong Kong, the participants visited local nuclear power plant, multiphase flow laboratory, and nuclear power plant simulation laboratory. For the final week in Taiwan, lectures covering the various areas in nuclear and renewable energy were given including energy policies and green energy developments, greenhouse gas regulations, carbon dioxide capture technology, hydrogen economy, fuel cells and etc. There were also visits to TPC Training Center, and National Synchrotron Radiation Research Center.

4. Strategic partners in Nuclear Education

As the only nuclear engineering program in Taiwan, NTHU also seek to promote international academic collaborations and cooperating with domestic industry and medicine, continuing its contribution to the development of nuclear energy and cultivation of young professionals. The domestic partners include Taiwan Power Company, Institute of Nuclear Energy Research, Industrial Technology Research Institute, and many private companies. For international partners, at present, as strategic partners in nuclear engineering education and research, NTHU has dual master program with Tsinghua University in Beijing and dual PhD program with the University of Liverpool (UoL) in England. Taking the dual PhD program as an example [2], the registered students have four years in which to complete a research project of qualified extent and depth. During the thesis study, the students will spend at least one year at the partner university, taking necessary courses and conducting research under the supervision of two advisors from both sides. The students successfully passed the specified requirements will be awarded their degrees from both institutions. Currently, there are two UoL students studying in NES and two NES students studying in UoL.

5. Conclusions

Nuclear power, as a vital option of low carbon energy, is playing a more important role and most likely will continue to exist in a long time. ESS and NES at NTHU provide a unique nuclear engineering and science program in Taiwan, offering various high-quality courses at both undergraduate and graduate levels in related areas. The well-organized curriculum attracts many young students that are interested in this field. On top of that, several co-sponsored summer school workshops designed for friendship exchange and broadening students' global perspectives in nuclear engineering are very successful. In addition to training young generation and conducting research, both faculties and students in ESS and NES also actively and continuously take part in campaigns providing correct nuclear energy and radiation related information to various societies and the general public in Taiwan.

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DISTANCE LEARNING IN NUCLEAR AND PROJECT MANAGEMENT

The Manchester Nuclear Technology Management (N-PDP) and Project Management (PM-PDP) Modular Programmes

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ABSTRACT

Manchester's Nuclear Technology Management programme (N-PDP) web-based 'distance-learning' part-time course is run in six-month's long modules. A few days at the University are required at the start of each module, followed by individual assignment work with university support by webinar and email. N-PDP is based upon a partnership with international companies. New build, operations and decommissioning are represented by the mature students* currently in the programme. The teaching draws on speakers with long experience of nuclear projects and the Dalton Nuclear Institute's wide range of research between the university and the industry. N-PDP runs in parallel with the School's long-established Project Management Professional Development Programme (PM-PDP) so that delegates on the nuclear programme can take a module from that programme.

1. Introduction

Teaching and research in project management began in the University of Manchester in 1965 [1]. The firsts in research work with industry included case studies of contract payment systems, project organisations, cost modelling and risk assessment of major projects. Most recently the impact of professional development on human skills, urgent unexpected work and the management of uncertainty in nuclear and other safety-critical projects [2]. The Project Management Group is based in the School of Mechanical, Aerospace & Civil Engineering. It runs major full-time and part-time PhD and MSc programmes and industry distance-learning programmes with partners in Brazil, Dubai, Singapore and the USA. The Group has been employed by many companies to run dedicated development programmes for their project and technology leaders and was a UK partner in the European Institute for Advanced Project Management consortium.

In 1999 Rolls-Royce plc together with international construction, manufacturing and software companies formed a consortium to sponsor a development programme for their project and project-related staff. In October 1999 they selected Manchester as their preferred academic partner for this new professional development programme, 'PM-PDP'. Dedicated senior University and company staff developed the programme, supported by a team of work package leaders and specialist advisors. Intense discussions followed on objectives, content, delivery and structure. By May 2000 a full number of delegates from the companies were studying the first modules in the new programme. This speed of development and agreement shows that industry and academia can work together swiftly and effectively [3].

2. Objectives of the Professional Development Programmes

The objectives for the first professional development programme were agreed to be:

- Create a community of project management
- Share good practice
- Encourage professionalism

* ~~The mature students from industry~~ taking these programmes are called '**delegates**'

- Develop staff at all levels
- Raise the profile of project management and its importance to business performance.

To achieve these objectives the programme was designed to provide:

- Management education at a postgraduate level
- A ladder of opportunity for those seeking a postgraduate qualification
- Preparation for professional examinations
- Single modules in specific subjects that can be taken alone
- Flexible learning to suit busy professional staff

3. The Modular Professional Development Programmes

A scheme of eight modules and learning outcomes was agreed as the vehicle for providing a flexible programme and enabling delegates to elect to follow only a single or selection of specific subjects. Each module is led by a member of university staff who is available to delegates by phone, email and a secure Virtual Learning Environment (Blackboard).

This web-enabled distance learning programme was designed so that busy professional staff need attend only a three day plenary session to start a module. The plenary events cover orientation, introductory lectures and guidance on learning skills, plus keynote lectures. Following that the delegates are supported by the tutors through the VLE, webinars and email as they work through the module reading, case studies, exercises and assignments. The programme is delivered in six-monthly cycles starting in April and October.

Each module requires some 150 hours of study and is worth 15 Credits. The delegates' work is assessed by assignments and an examination. The successful completion of four modules leads to a University of Manchester Postgraduate Certificate. Delegates who complete eight modules are awarded a University of Manchester Post Graduate Diploma. Those who go on to successfully complete a dissertation gain the University of Manchester MSc degree. To be eligible for the Diploma or MSc delegates are normally expected to have an existing qualification equivalent to that of lower second class Honours degree from a UK university.

The modules are subject to evaluation and review with the companies and an academic external examiner. Delegates are encouraged to complete feedback questionnaires to help the programme directors ensure that the programme continues to meet the needs and demands of industry and public services in the 21st century.

The programme is accredited by UK and US professional societies.

4. The Management of Nuclear Technology Professional Development Programme (N-PDP)

Following this model the Manchester Nuclear Technology Management programme (N-PDP) has been designed for three groups of sponsored delegates:

- Graduates in nuclear industry organisations who are looking to develop their career into management
- Engineers and managers with experience outside the nuclear sector who are moving into it
- Established nuclear practitioners looking to widen their horizons

The modules for the N-PDP programme were designed by a team of members of the Project Management Group and the Dalton Nuclear Institute working in partnership with leading companies in nuclear new build, operations and decommissioning [4].

The scope of the modules is shown in Table 1. The programmes start with a foundation module. In N-PDP this module 'Essentials of Delivering Nuclear Technology' consists of sections on the challenges of delivering nuclear technology and the fundamentals of project management for the nuclear environment. It is a broad introduction providing the basis for progressing to the specialist modules shown in the tables. The final module includes preparation for the MSc dissertation.

N-PDP is endorsed by the IAEA.

N-PDP delegates can arrange to take one of the seven PM-PDP specialist modules.

N-PDP MODULES	PM-PDP MODULES
Essentials of Delivering Nuclear Technology	Foundation Module
Decommissioning Nuclear Facilities	Project Strategy and Risk
Fundamentals of Nuclear Energy	Planning and Resource Management
Nuclear Reactors and Nuclear Facilities	Project Cost Management
Managing Nuclear Installation Safety	Commercial and Procurement
The Nuclear Fuel Cycle	Systems Engineering and Project Management
Safeguards, Security and Safety Management	People, Organisation and Culture
Research Methods	Project Quality Management
	Research Methods

Table 1: The Modules in the N-PDP and PM-PDP Programmes

The expertise in reliability engineering and asset management required by engineers and managers in all industries are the subject of another professional development programme, REAM-PDP [5].

The modules available in these distance-learning programmes thus cover the life-cycle of a nuclear asset through to decommissioning illustrated in Figure 1.

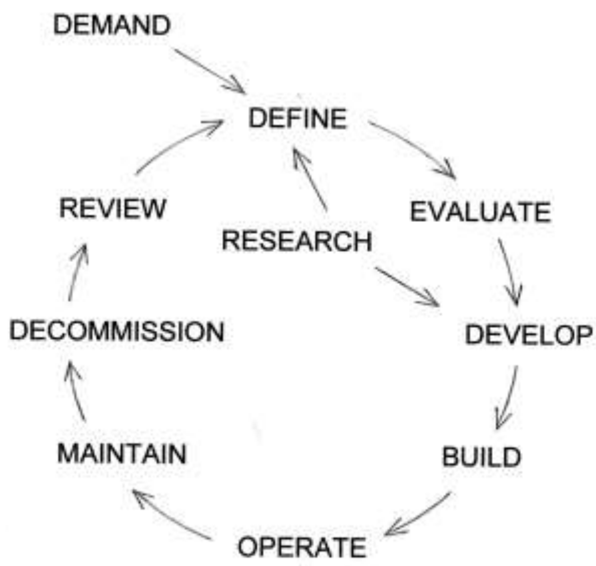

Figure 1: Asset Life Cycle

5. Conclusions

A combination of intensive residential events coupled with web-enabled learning appears to provide a robust learning and professional development platform. Flexibility in the work for a module has suited many delegates. Delegates who initially elected to take one module have then chosen to take more.

Attendance at Manchester requires only a few days away from offices and home per module.[†] It does require the commitment of delegates' time and their employers' support. The dedication of delegates to completing the modules shows that professional development programmes meet a great demand for advancing competence. Feedback from them confirms the value to them and their companies of the opportunities to reflect on how best to apply theory and the lessons of case studies to the challenges of their work.

The mode of delivery of the programmes is not complex but building these programmes requires the understanding and management of expectations for all stakeholders. Freezing the learning objectives, content and delivery of the first programme depended upon many meetings of industry specialists and academics. It all demanded their time. The meetings established a team spirit and common language between all levels concerned in the companies and the university that was very helpful through the continuing work of reviewing and up-dating the modules. Maintaining this is greatly helped by an active and empowered 'steering' group of company representatives and feedback to them from programme delegates.

Professional development does not come cheap, to employers or delegates. How its effectiveness and the return on the investment can be measured was demonstrated in independent research project [6].

Over 350 delegates from many different companies and government organisations have now successfully completed these Manchester programmes. The modular structure described provides a model for others to follow.

[†] ~~Delegates from Austria, Brazil and~~ Saudi Arabia are currently attending the programmes

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NUCLEAR EDUCATION & TRAINING- CRITICAL FOR PREPARING NUCLEAR HUMAN RESOURCES ACROSS WHOLE NUCLEAR VALUE CHAIN

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1. Introduction – Stakeholders in a Nuclear Power Programme (NPP)

The safe and successful introduction and expansion of a Nuclear Power Porogramme (NPP) requires the support and implementation by a diverse group /team of stakeholders (see Fig 1)

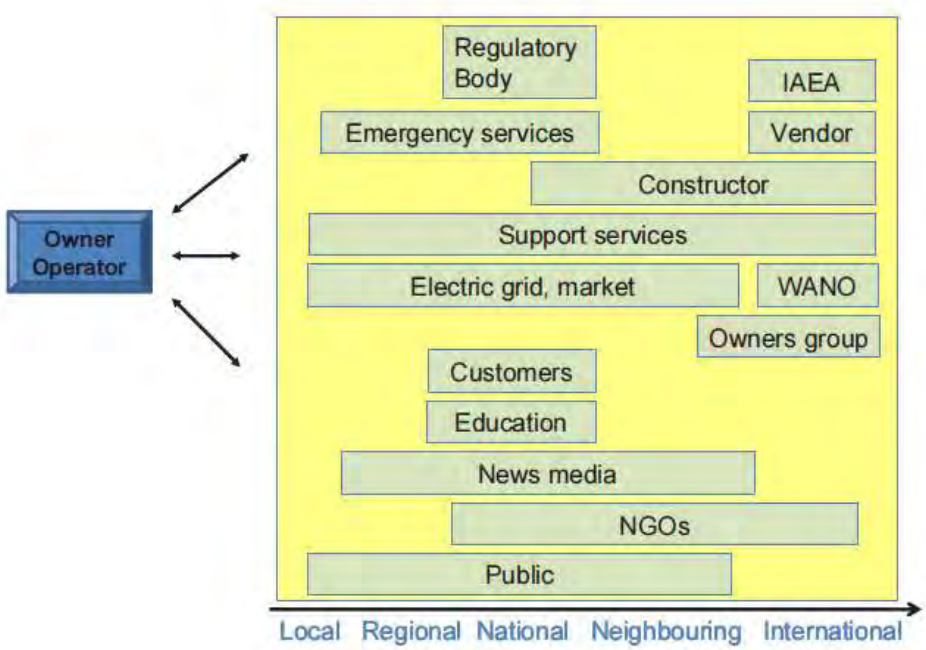


Fig 1. Stakeholders in a Nuclear Power Programme (NPP)

2. Managing Human Resources in the Field of Nuclear Energy-IAEA

The IAEA Nuclear Energy Series NG-G-2.1 titled " Managing Human Resources in the Field of Nuclear Energy", IAEA ,2009 has outlined a diverse and multitude of organizations that require competent human resources to support a Nuclear Power Programme and for new NPP builds (see Fig 2).

Fig 2: Human Resources for a Nuclear Power Programme (NPP) and for new NPP Builds- by IAEA

Note : The segment in red- Media Agencies and Financial Institutions is the author's proposal for additional agencies requiring competent people

This paper strives to share with the education and training stakeholders, that the task of educating and training students is not solely to prepare them to work in a nuclear power plant, but importantly also to train human resources to support other organizations that require skilled and competent personnel in nuclear related field including Government agencies and Ministries, Business and Industry, Financial sector, International agencies and media agencies, amongst others.

3. Identification of suitable Nuclear Education and Training syllabus and courses

As nuclear education and training (E&T) stakeholders deliberate and discuss to identify suitable syllabus and courses to offer for education and training to support NPP, it is critical that the nuclear fuel cycle (See Fig 3) , the IAEA's Milestone Approach for National Infrastructure Development (see Fig 4) and nuclear new build supply-chain (see Fig 5) are taken into consideration in the selection and introduction of relevant courses by Universities and training Institutions to nurture and educate skilled manpower for the nuclear power industry.

Fig 3

Nuclear Fuel Cycle, includes the :

1) **Front-end fuel markets** (i.e. uranium mining through fuel fabrication).,
2) The overall **nuclear reactor sector** (nuclear reactor planning, construction , operations and maintenance and decommissioning) , as well as the
3)**Back-end of the fuel cycle**.(fuel treatment /reprocessing, storage and disposal)

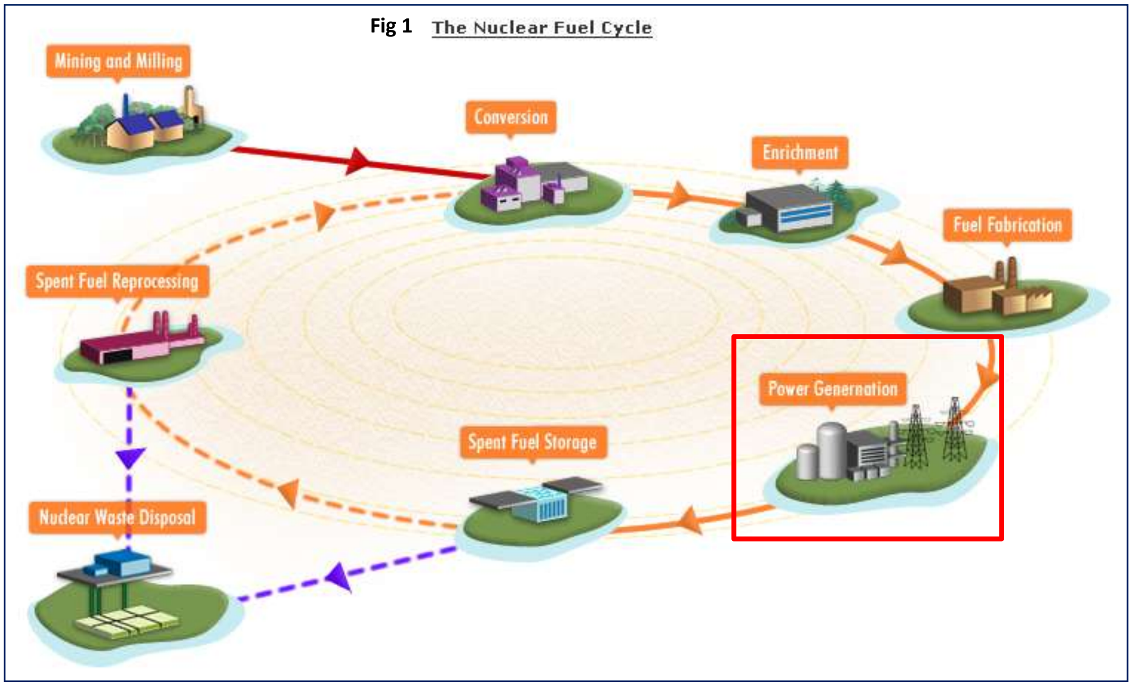
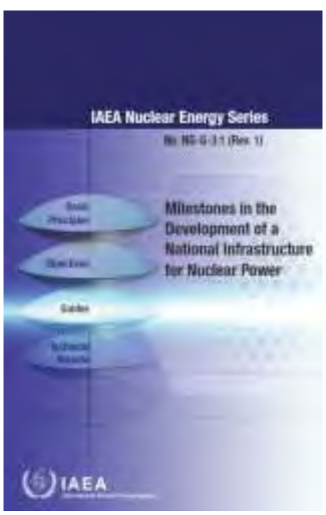
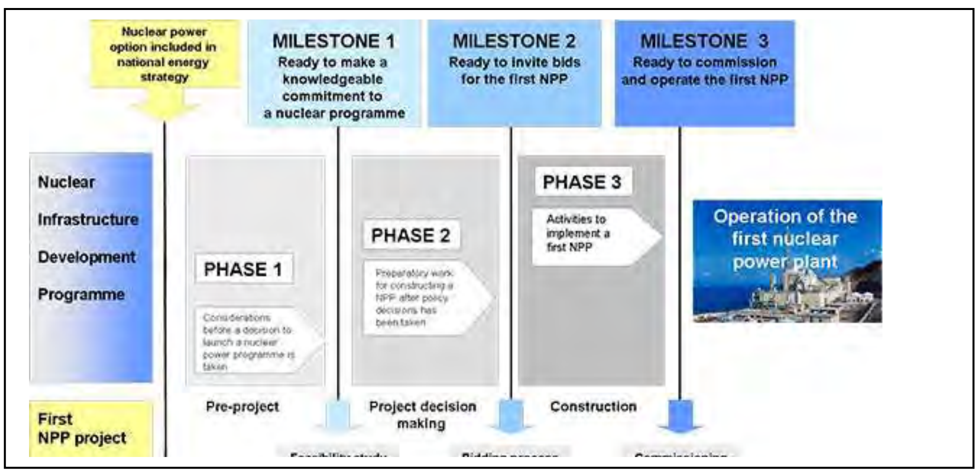


Fig 3: Nuclear Fuel Cycle

4 Milestones in the Development of a National Infrastructure for Nuclear Power





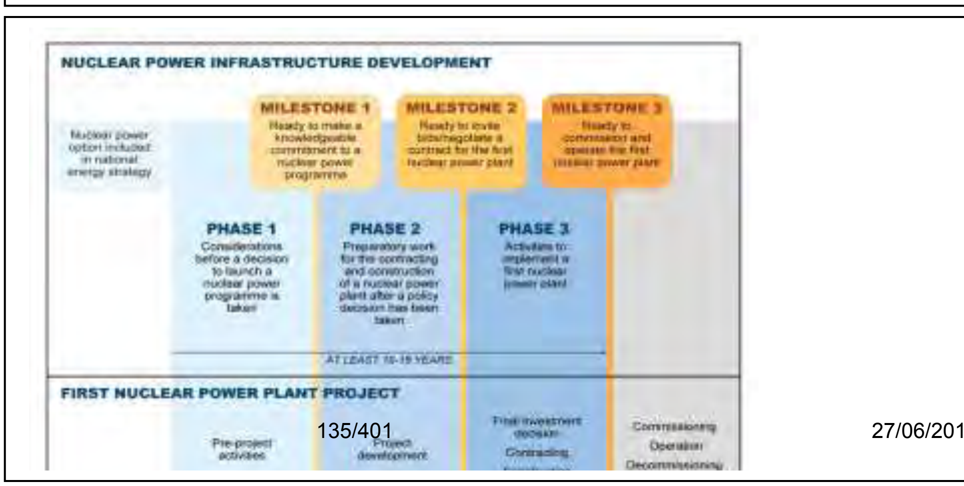


Fig 4: Milestone Approach to Nuclear Power Infrastructure Development

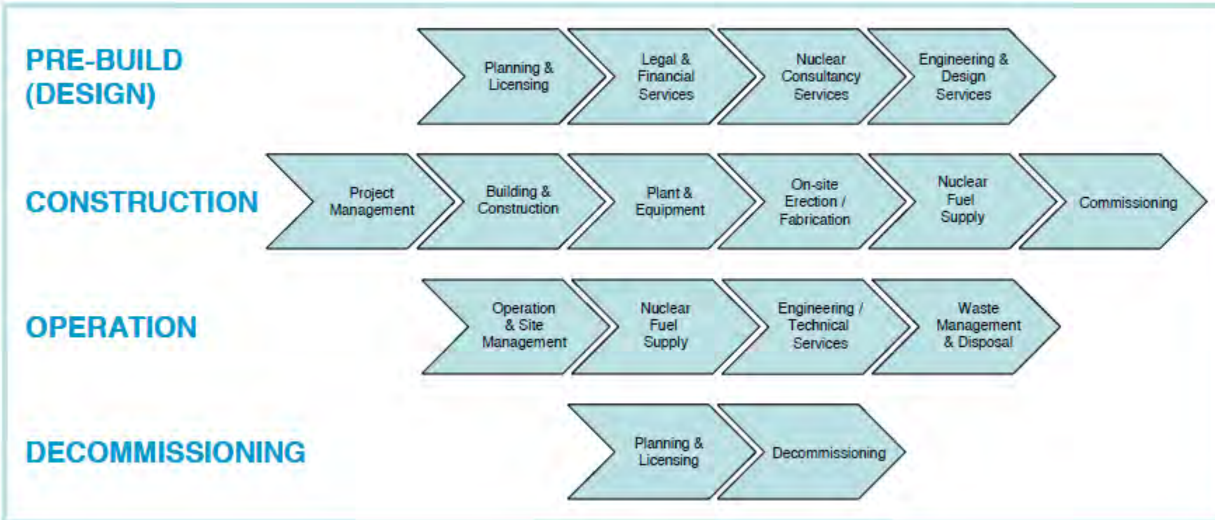


Fig 5: Elements of Nuclear New build Supply Chain

4. Integrating the Development of a National Infrastructure for Nuclear Power and Elements of Nuclear New Build Supply Chain to identify suitable Nuclear E&T

This paper introduces a strategy for Integration of the Development of a National Infrastructure for Nuclear Power and Elements of Nuclear New Build Supply Chain as key to identifying suitable Nuclear E&T for stakeholders in the Nuclear Value Chain (see Fig 6)

6 Integrating the Development of a National Infrastructure for Nuclear Power and Elements of Nuclear New Build Supply Chain to identify suitable Nuclear E&T

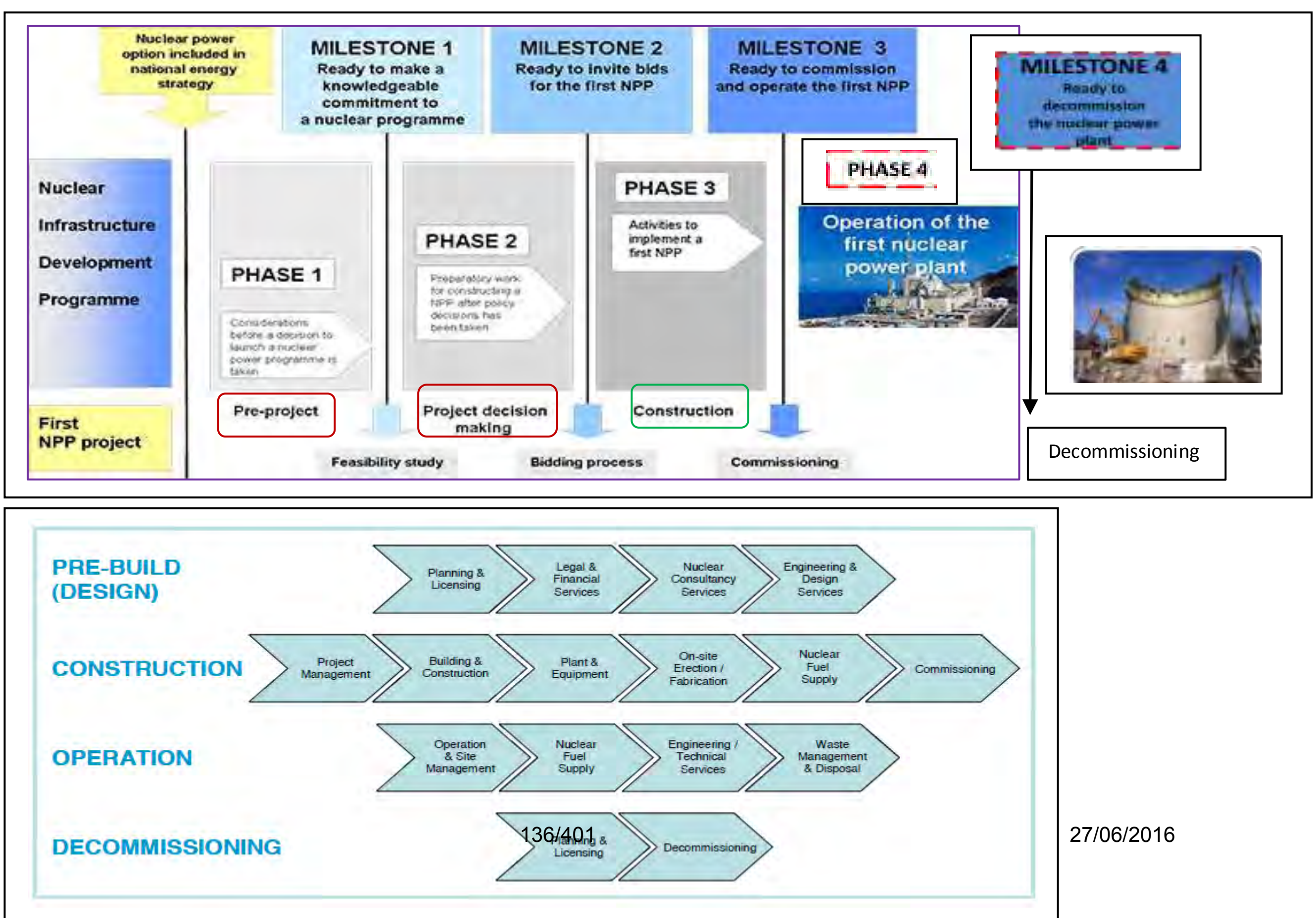


Fig 6: Integration of the Development of a National Infrastructure for Nuclear Power and Elements of Nuclear New Build Supply Chain as strategy to identify suitable Nuclear E&T for stakeholders in the Nuclear Value Chain

5. Stakeholders and Human Resources to support NPP

It is critical for countries preparing Nuclear HRD to support NPP to recognize that in addition to training and educating students at colleges and universities who will graduate to become scientists, engineers, and other professionals , offering training for working professionals via continuing professional development courses (CPD), and special courses for Nuclear leaders and senior management are also essential . (see Fig 7 and Fig 8)

Additionally it is also fundamental to introduce specialized courses as introduction to nuclear power for Politicians, Policy makers, Press or media as well as Business representatives in selected industry sectors including finance and banking, manufacturing , construction and services as their decision, involvement and investment is important to support the successful and efficient introduction and implementation of a nuclear power programme. (see Fig 7 and Fig 8)

Fig 7 Stakeholders and Human Resources to support NPP

Fig 8. HUMAN RESOURCES to Support NPP
POLITICIANS, POLICY MAKERS, PROFESSIONALS, TECHNICIANS & CRAFTSMEN, PRESS & PUBLIC

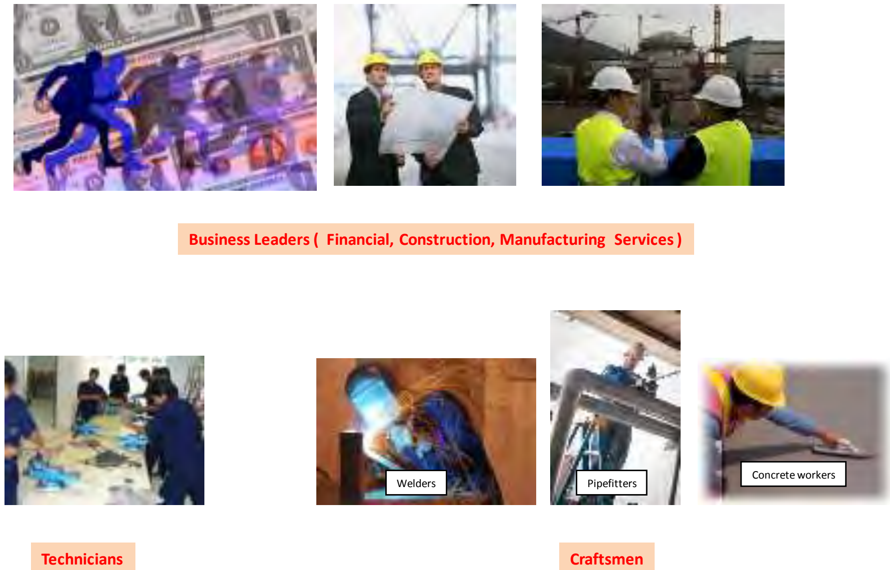


Fig 8 Stakeholders and Human Resources to support NPP

6. *Nuclear Awareness and Nuclear E&T for Stakeholders for NPP*

Fig 9 outlines Nuclear Awareness and Nuclear E&T Programmes for selected stakeholders

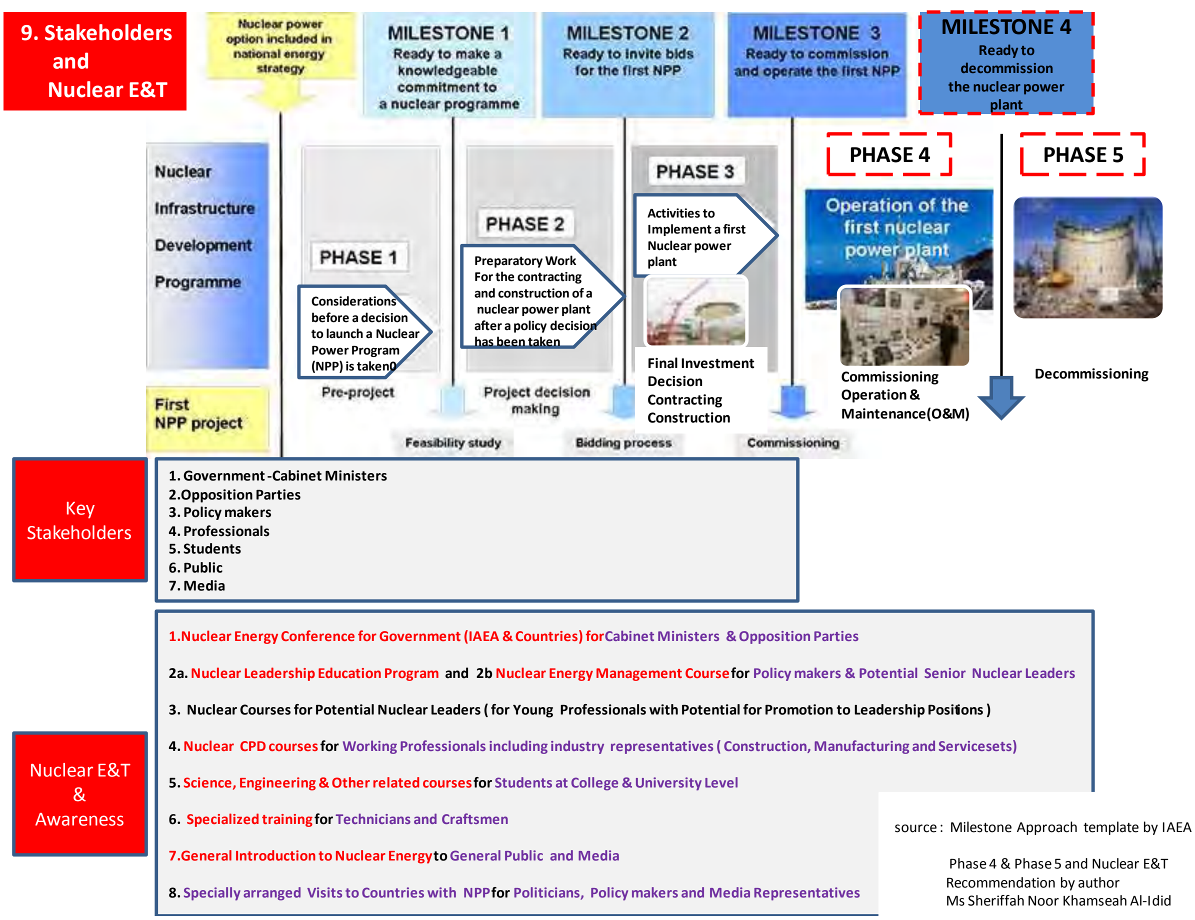


Fig 9 Nuclear E&T and awareness for Stakeholders to support NPP

6. At the early stages of Phase 1 : Pre-project , before a decision to launch a nuclear power programme and Phase 2: Project Decision making is taken , initiatives to introduce Nuclear Awareness and Nuclear E&T must target critical stakeholders including Politicians , Ministers and Opposition party members , High Level and senior Government Officials , Working Professionals , Media Representatives and the Public

6a. Nuclear Energy Conference for Ministers by IAEA

The International Atomic Energy Agency (IAEA) organizes three years once a Nuclear Energy Conference for Ministers (see Fig 10)

Fig 10 Nuclear Energy Conference for Ministers organized by the IAEA

However as this Conference is generally attended by Ministers of Energy who are mostly converted to Nuclear Energy as one option for diversification of energy sources and enhancing energy security, it is recommended that the IAEA considers organiziing this Ministerial Conference on a more regular basis and involving and engaging other Ministers with portfolio also equally important to support a Nuclear Power programme (see Fig 11)

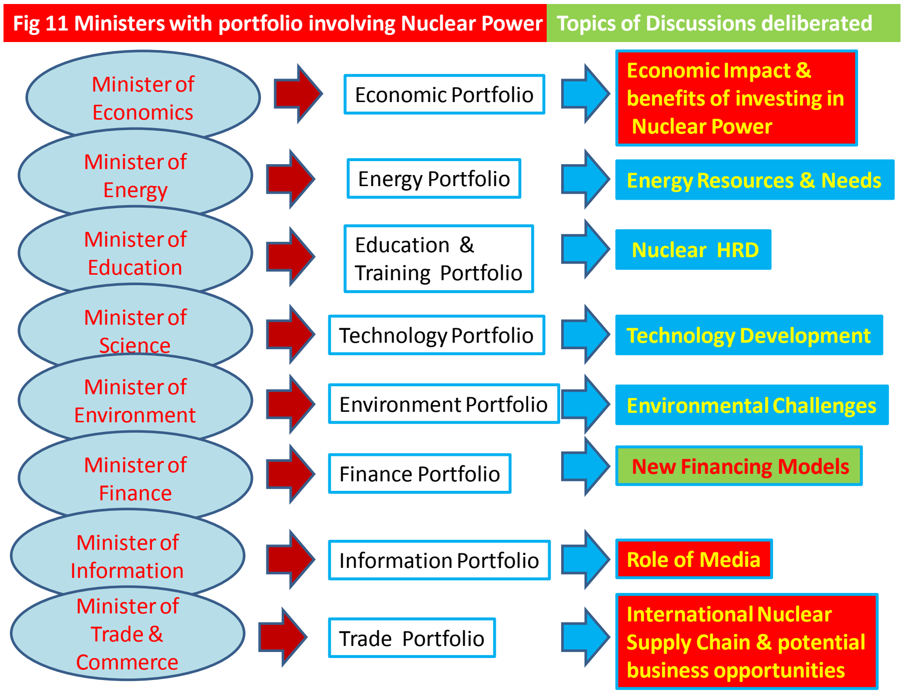


Fig 11. Proposing to the IAEA to organize Nuclear Energy Conference for other Ministers apart from Minister of Energy but with Portfolio important to support a Nuclear Power Programme

6b. Nuclear Energy Conference for High Level Senior Government Officials

i) MIT's INLEP

In view that whilst it is critical for Politicians including Cabinet Ministers and members of the Opposition to decide and support the introduction of a Nuclear Power Programme for NPP to be realized , the actual detailed planning for NPP is undertaken by High Level and Senior Government Officials

Hence it is fundamental that Nuclear Education and Training are developed and introduced for these stakeholders . The MIT in USA has introduced in 2013, INLEP- International Nuclear Leadership Education Programme , a course of a maximum of 20 people for a duration of 9-10 days for High level Government Officials, Senior Executives of Nuclear Operating Companies and Senior Regulators (see Fig 12) covering areas of Governance structure, business strategies, operational practices and technologies needed to develop successful , safe and secure energy programme.

Fig 12. Nuclear Education & Training Programe for High Level/ Senior Government Officials, Policy & Decision Makers

MIT International Nuclear Leadership Education Program (INLEP)

INLEP, provide leadership education in the governance structure, business strategies, operational practices and technologies needed to develop successful, safe and secure nuclear energy programme for:

-High level Government Officials
-Senior Executives of nuclear operating companies
-Senior Regulators

-Participation is by invitation only. Each class will consist of about 20 participants, drawn from several countries. The instructors include faculty from MIT and other universities as well as an group of prominent experts and practitioners from industry and government.
- Comprise two modules (each module 9-10 day duration) and site visits

First Course offering in 2013, continued in 2014 and 2015

Nuclear Leadership

- Politicians / Ministers
- Policy & Decision Makers
- Management of Nuclear Power Plants
- Management of Nuclear R&D Institutes

One week programme – This format of the IAEA Nuclear Energy Management School is a short and condensed version of the School and puts stronger emphasis on strategic and policy issues which need to be understood by those in key leadership roles in nuclear organizations.

It also emphasizes issues at the national and international level in the nuclear context and provides a broad overview of important nuclear issues and policy.

This curriculum is well suited for **nuclear organization leaders, newly appointed senior managers, managers who may be new to nuclear organizations, or senior nuclear government policy makers and decision makers**.

Fig 12. MIT's INLEP programme for Senior Officials of Government, Nuclear Operating Companies and Regulatory bodies

Ii) Certificate Course by IAEA

The International Atomic Energy Agency (IAEA) its IAEA School of Nuclear Energy Management offers a Certificate Course of one week duration which provides a broad overview of important international and national nuclear issues and policy for senior nuclear government policy and decision makers, nuclear organization leaders , newly appointed senior managers and managers who may be new to nuclear organizations

7.Nuclear Energy courses for Working Professionals (Working Nuclear Managers and nuclear professionals with potential to move into management)

At the Operational level, as working Professionals skilled and competent in Nuclear energy are required to assist and support the High Level and Senior Government Officials, Policy and Decision Makers thus it is imperative that suitable and relevant education and training programmes are introduced and offered to these stakeholders

7a. International Nuclear Management Academy (INMA) Nuclear Technology Management (NTM) Master's level programmes by the IAEA

INMA aims to make high quality management education that is tailored to the specific needs and challenges of the nuclear sector both more available and more accessible to :

- working nuclear managers or
- nuclear professionals with potential to move into management.

INMA programmes are intended for students in both developed and developing countries. INMA Member Universities are encouraged to offer courses in the form of online and distance learning, and also in short-format courses and on a part-time basis. This is intended to give working nuclear professionals more flexibility and options to successfully complete programmes. (see Fig 13)

Fig 13. Nuclear Education & Training for Nuclear Leaders
(Professionals with Potential to be Leaders)

Nuclear Leadership

- Politicians / Ministers
- Policy & Decision Makers

Management of Nuclear Power Plants
Management of Nuclear R&D Institutes

International Nuclear Management Academy (INMA) is ***a framework facilitated by the IAEA, through its*** Nuclear Knowledge Management (NKM) Section in the Department of Nuclear Energy ***in collaboration with nuclear engineering and business faculties at universities and with nuclear employers around the world***. Its goal is to support participating universities in the implementation of high quality master's level management programmes for the nuclear sector

NMA aims to make high quality management education that is tailored to the specific needs and challenges of the nuclear sector both more available and more accessible to :
- ***working nuclear managers or***
- ***nuclear professionals with potential to move into management.***

INMA programmes are intended for students in both developed and developing countries. INMA Member Universities are encouraged to offer courses in the form of online and distance learning, and also in short-format courses and on a part-time basis. This is intended to give working nuclear professionals more flexibility and options to successfully complete programmes.

Several participating universities have started work on introducing **INMA Nuclear Technology Management (NTM) master's level programmes,** with the first already commence in the fall of 2015 and others being introduced over the next one to three years.

National Research Nuclear University
(Moscow Engineering Physics Institute)

The **Manchester University in the United Kingdom** has recently introduced the first Nuclear Technology Management Programme. This programme is expected to be endorsed by IAEA as the first successfully peer reviewed INMA programme by the fall of 2015 . National Research Nuclear University (MEPhI) in the Russian Federation is expected to be the next university to introduce a Nuclear Technology Management Programme, and is targeting to start-up and be fully endorsed by the fall of 2016

Fig 13: Nuclear E&T for Nuclear Leaders (Professionals with Potential to be Leaders)

7b. 2 and 3 weeks courses for young professionals working in nuclear organizations with managerial interest and potential

The IAEA through its School of Energy Management offers 2 and 3 weeks Certificate courses for young professionals working in nuclear organizations who show some managerial interest and potential, (see Fig 14)

Fig 14. Nuclear Education & Training for Nuclear Leaders
(Professionals with Potential to be Leaders)

Nuclear Leadership

- Politicians / Ministers
- Policy & Decision Makers
- Management of Nuclear Power Plants
- Management of Nuclear R&D Institutes

CERTIFICATE COURSE
Participants of each IAEA NEM School interact and learn from some of the best specialists in the global nuclear industry and from the IAEA.

The IAEA NEM School is offered in several programme and curriculum formats that can be tailored to specific needs on request and can be conducted in three different formats, based on a member state's particular needs:

Three week programme - This format of the IAEA Nuclear Energy Management School is well suited for **young professionals working in nuclear organizations who show some managerial interest and potential**.

Two week programme – This format of the IAEA Nuclear Energy Management School is well suited for **first level or middle level managers in nuclear facilities or organizations.** It will provide them with essential knowledge to better understand their role in the broader organizational and industry context and prepare them to work at a higher level in their organizations. A broad overview of nuclear energy challenges and policy issues is provided, with an emphasis being placed on facility management perspectives, and participant experience sharing, case study team work.

Fig 14: IAEA School for Energy Management Certificate Course (2 and 3 weeks) for Nuclear Professionals with Potential to be Leaders

7c: IAEA and other Agencies Collaboration offering Courses on Nuclear Energy Management

In view of the urgent need and great demand to train working professionals , several international agencies have established collaboration with the IAEA to jointly organize Nuclear E&T for these stakeholders.

These include Joint ICTP-IAEA School on Nuclear Energy Management (see Fig 15), Japan-IAEA School on Nuclear Energy Management (Fig 16) and UAE-IAEA School on Nuclear Energy Management (see Fig 17)

15c. Nuclear Education & Training for Nuclear Leaders
(Professionals with Potential to be Leaders)

ICTP International Centre for Theoretical Physics

IAEA

2 November 2015 - 13 November 2015
Trieste ITALY
International Atomic Energy Agency (IAEA)

3-14 October 2016

Nuclear Leadership

- Politicians / Ministers
- Policy & Decision Makers

Management of Nuclear Power Plants
Management of Nuclear R&D Institutes

Joint ICTP-IAEA School on Nuclear Energy Management

The Abdus Salam International Centre for Theoretical Physics (ICTP, Trieste, Italy) in co-operation with the International Atomic Energy Agency (IAEA, Vienna, Austria) is jointly organizing the School of Nuclear Energy Management

The purpose of this school is to provide a unique international educational experience aimed at building future leadership in managing nuclear energy programmes from among promising young professionals, particularly from newcomer countries that seek to develop nuclear power or other nuclear applications, who show promise as future leaders of the nuclear industry, academia and public sector entities. It will enable the transfer of IAEA specific knowledge to Member States towards their capacity building efforts.

The prospect of a continuing worldwide use of nuclear technologies – for electricity generation and electricity and applications in medicine, agriculture and industry, as well as the ageing cadres in the field points to the need for new cadre of nuclear professionals. A highly competent management is vital to the success at all stages of nuclear programmes. The school will train young professionals from developing and developed countries with managerial potential on aspects of the industry to ensure their broad understanding of the current issues that need to be tackled in their countries. The School will consist of a series of keynote presentations by leading IAEA specialists on topics relevant to managing nuclear energy programmes followed by practical sessions. All participants will be expected to be actively involved in discussions, assigned projects, panel reviews and other activities.

The following topics will be covered:

- **World Energy Balance, Geopolitics and Climate Issues;**
- **Energy Planning, Energy Economics and Nuclear Power Economics and Finance;**
- **Nuclear Power - Technology and Life Cycle;**
- **Nuclear Safety and Security;**
- **Nuclear Law, International Conventions and Relevant Mechanisms;**
- **Nuclear Non-Proliferation and Safeguards;**
- **Human Resource Development and Knowledge Management;**
- **Nuclear Leadership, Management and Sociology;**
- **Emergency Planning and Preparedness**
- **Radioactive Waste Management and Decommissioning**
- **Communicating Radiation Risks to the Public**
- **IAEA Support for Nuclear Power Development.**

Fig 15: ICTP-IAEA School of Nuclear Energy Management for Working Professionals with Potential to be Leaders

Fig 16. Nuclear Education & Training for Nuclear Leaders
(Professionals with Potential to be Leaders)

Japan-IAEA Joint Nuclear Energy Management School

1 to 17 June, 2015

11-27 July 2016

Nuclear Leadership

- Politicians / Ministers
- Policy & Decision Makers

Management of Nuclear Power Plants
Management of Nuclear R&D Institutes

Japan- IAEA Joint Nuclear Energy Management School

This School will be organized by the Japan Nuclear Human Resource Network (JN-HRD.net), Japan Atomic Energy Agency (JAEA), University of Tokyo , Japan Atomic Industrial Forum (JAIF) and JAIF International Cooperation Centre (JICC) in Cooperation with the International Atomic Energy Agency (IAEA)

The purpose of the Japan-IAEA Joint Nuclear Energy Management School is to provide a unique international educational experience aimed at building future leadership to manage nuclear energy programmes, to nourish a wide range of knowledge on issues related to the peaceful use of nuclear technology and to broaden individual networking with people interested in 1 to 17 June, 2015 all over the world.

The Session topics will be covered:

- **Energy Policy Making and the Role of Nuclear Power**
- **Management of New Nuclear Power Projects**
- **Nuclear Material Control;**
- **Protecting People and the Environment;**
- **Developing National Capacity for Nuclear Energy**

Participants Qualification:* *Young Professionals (preferrably less than 40 years old) with managerial potential who have worked in the nuclear field for at least 3 years and shall make good use of the fruits of the Management School for their current and/or future jobs

Suitable for : Employees of NPPs, R&D Organizations, Utilities, Regulators, Suppliers, Executive Authorities, Education & Training Organizations

Fig 16: Japan -IAEA School of Nuclear Energy Management for Working Professionals with Potential to be Leaders

Fig 17. Nuclear Education & Training for Nuclear Leaders (Professionals with Potential to be Leaders)

17 - 28 May 2015, Abu Dhabi, UAE

Nuclear Leadership

- Politicians / Ministers
- Policy & Decision Makers

Management of Nuclear Power Plants
Management of Nuclear R&D Institutes

Joint UAE-IAEA Nuclear Energy Management School

The Nuclear Energy Management School, organized by the International Atomic Energy Agency (IAEA) in cooperation with the Khalifa University (KU), the Federal Authority for Nuclear Regulation (FANR), Emirates Nuclear Energy Corporation (ENEC) and the Critical Infrastructure and Coastal Protection Authority (CICPA), will be held from 17 to 28 May 2015 in Abu Dhabi, United Arab Emirates.

The purpose of the Joint UAE-IAEA Nuclear Energy Management School is to provide a unique, international educational experience aimed at building future leadership to manage nuclear energy programmes, to promote and foster knowledge of a wide range of issues related to the peaceful use of nuclear technology, and to provide a unique worldwide networking opportunity for future managers in the area of nuclear energy.

- **Energy Policy Making and the Role of Nuclear Power**
- **Management of New Nuclear Power Projects**
- **Nuclear Material Control;**
- **Protecting People and the Environment;**
- **Developing National Capacity for Nuclear Energy**

***Participants Qualification:** Young Professionals (preferrably between 25 and 40 years old) with managerial potential from developing countries with plans to newly introduce nuclear power and from countries with an established nuclear programme*

***Suitable for :** Employees of NPPs, R&D Organizations, Utilities, Regulators, Suppliers, Education & Training Organizations*

The school is open to approximately 35 participants of which 15 are foreign participants from participating Member States of TC Project RAS/2/2015 and Member states in Asia and the Pacific embarking or considering embarking on NPP.
Their participation to this NEM School should be supported through their respective National TC project

Fig 17: Japan -IAEA School of Nuclear Energy Management for Working Professionals with Potential to be Leaders

8. Phase 1 and Phase 2 Nuclear E&T courses offered aligned to the Milestone Approach for National Infrastructure Development for NPP

South Korea's Nuclear Training Centre (NTC) under KAERI has introduced specialized training courses relevant for stakeholders in Phases 1 and 2 of the Milestone Approach for National Infrastructure Development for NPP (see Fig 18)

Fig 18: KAERI's Training Programme by Course according to Phases 1-4 of Milestone Approach for National Infrastructure Development for NPP

As can be observed in Fig 18, in Phase 1 the demand and focus is more on policy, planning, safety and training. Thus General Key Issues in the World Nuclear Industry today, Nuclear Energy Policy , Planning and Nuclear Power Project Management , Safety Assessment for Nuclear Reactors, Network for Education in Nuclear Technology , Capacity Building for Emerging Countries were identified as amongst some of the Nuclear E&T areas critical to support NPP are being offered by KAERI to support IAEA members states

Phase 2 covers more technical requirement and thus courses such as Fundamentals of PWR with PC –based Simulators, Project Management and Construction of Nuclear Power Plants are offered by KAERI

9. At the next stage of Phase 3 covering Decision, Final Investment, Contracting and Construction, comprising activities to implement a first a nuclear power plant , initiatives to introduce Nuclear Awareness and Nuclear E&T must target critical stakeholders including High Level and senior Government Officials, Industry Officials and representatives in the Construction , Manufacturing and services sectors as well as Public

The IAEA has outlined that Professionals, Technicians and Craftsmen have important roles to assume in the different stages of nuclear power development .During plant construction 100 professionals, 400 technicians and 2700 craftsmen are required to support NPP. (see Fig 19)

Fig 19 : Roles and Opportunities for *Professionals, Technicians as well as craftsmen*

Source : Manpower Development for Nuclear Power , IAEA 1980 :	Number *Professionals (P)*	%	Number *Technicians (T)*	%	Number *Craftsmen (C)*	%	Number *Total (T)*
i) ***Pre-project activities,***	38	95 %	2	5 %	-	-	40
ii) ***Project management***,	99	87 %	15	13 %	-	-	114
iii) ***Project engineering***,	240	56 %	190	44 %			430
iv) ***Procurement*, **	28	70 %	12	30 %			40
v) ***Quality assurance/quality control***, QA/ QC	50	42 %	70	58 %			120
vi) ***Plant construction***,	100	3 %	400	13 %	2700	84 %	3200
vii) ***Commissioning***,	50	22 %	60	26 %	120	52 %	230
vii) ***Operation and maintenance (O&M)***	55	20 %	180	67 %	35	13 %	270
viii) ***Fuel cycle activities*** and	17	12 %	123 (88 %)				140
ix) ***Nuclear licensing and regulation***.	65		-	-	-	- 65	plus
Total Numbers of Manpower	*742*	*16 %*	*929+*	*20 % +*	*2855+*	*62% +*	*4584*

Fig 19: Manpower needs for Nuclear power Programme

Thus, in terms of manpower required to support a nuclear power programme (NPP), countries must prepare a nuclear workforce by providing relevant nuclear training courses for students at colleges and universities and also for technicians at vocational schools and craftsmen at construction training centres and academies

It is also vital to recognize the various skills and competencies required (Please refer to Fig 5- Elements of Nuclear New Build Supply Chain) for Professionals (see Fig 20), Technicians as well as craftsmen (Fig 21)

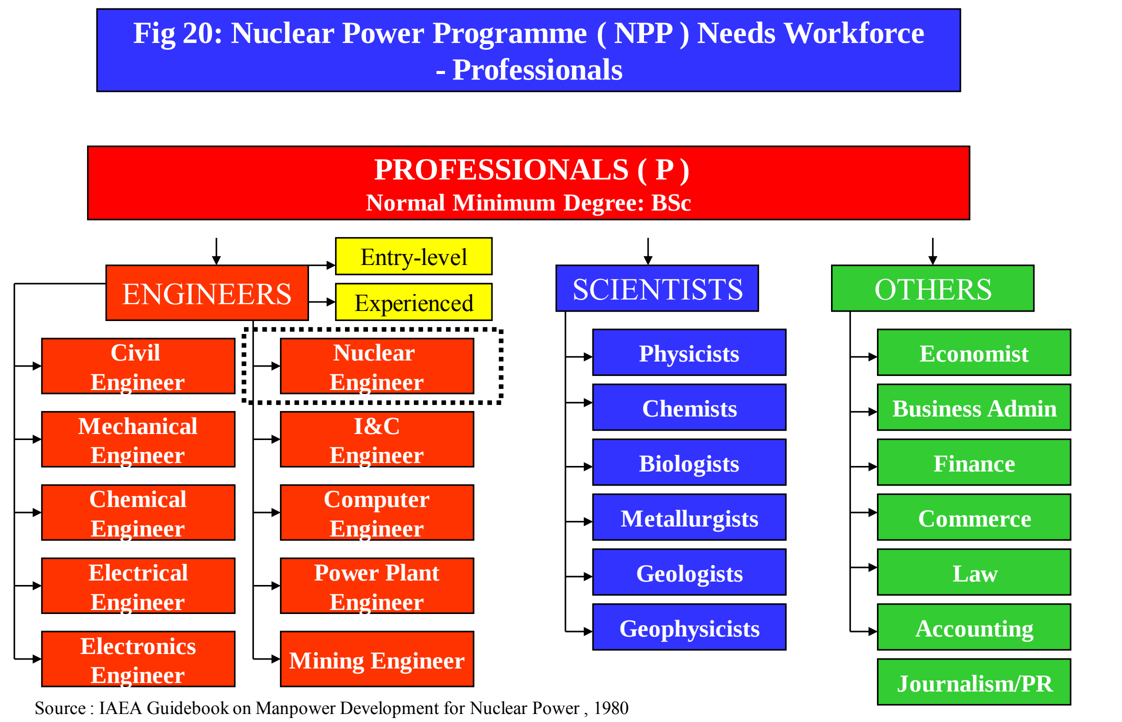


Fig 20: Professionals required to support a Nuclear Power Programme (NPP)

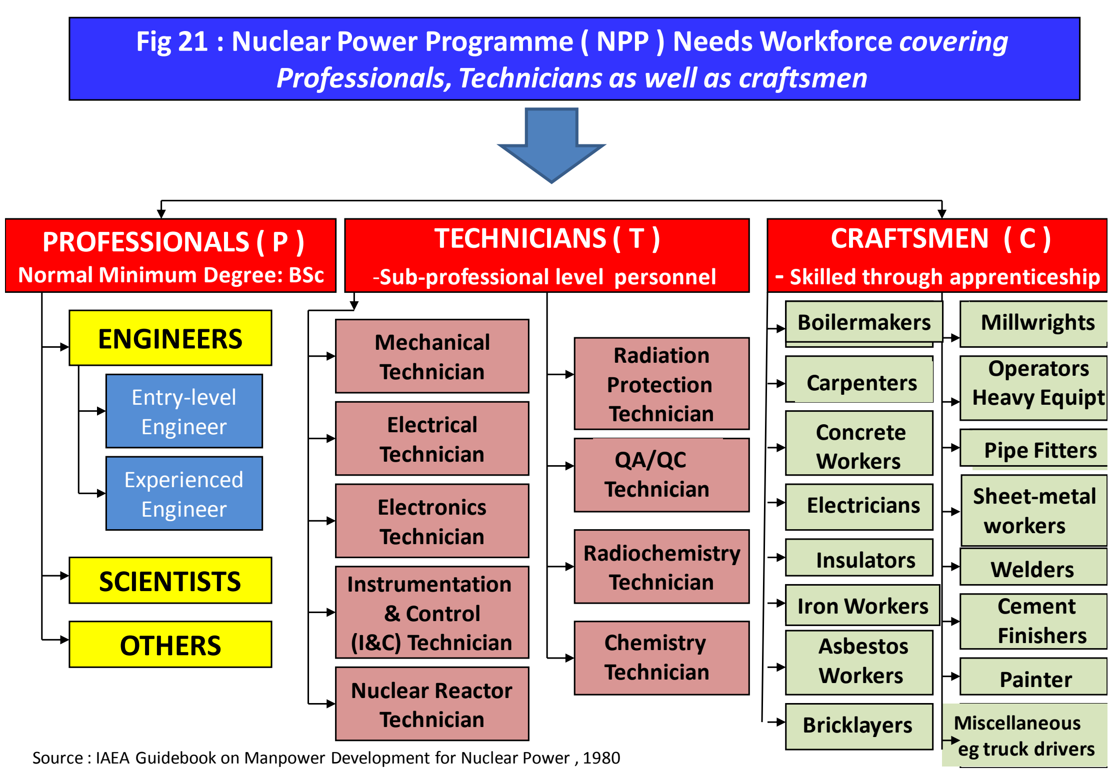


Fig 21: Professionals, Technicians and Craftsmen required to support a Nuclear Power Programme (NPP)

10. Nuclear Education & Training throughout the Nuclear New Build Supply Chain - The UK's Best Practice

Cogent and the National Skills Academy – Nuclear (NSAN) had reported that the UK's Civil Nuclear Industry in 2009 comprise a total of 43,690 personnel in a diverse work scope highlighted in Fig 22.

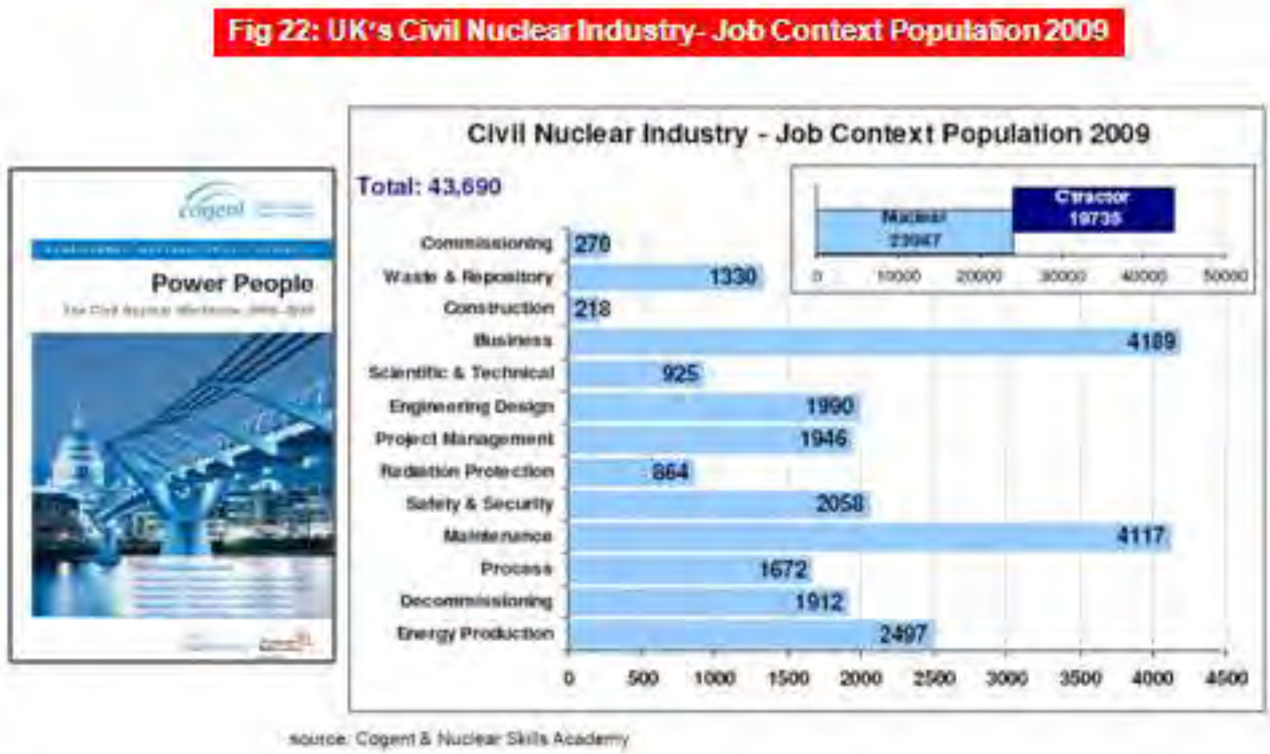


Fig 22: UK's Civil Nuclear Industry- Job Context Population 2009

The civil nuclear industry today provides employment for 44,000 people. Of these, 24,000 are employed directly by the nuclear operators across three sectors – electricity generation, decommissioning, and fuel processing. The remainder is employed in the direct supply chain to the nuclear industry. The sectors are split across both public and private ownership, with the latter being prevalent in electricity generation.

Of the 24,000 employed directly by the nuclear operating companies, decommissioning (12,000) is by far the largest sector, followed by electricity generation (7,500) and fuel processing (4,500)

This paper outlines best practices in nuclear education and training offered by the United Kingdom which trains students, professionals, technicians across the whole new build supply chain (see Fig 23 -Fig 27)

a) Pre-build Stage

With reference to the Pre-build Stage , several universities in the United Kingdom offer courses covering Planning and Licensing, Legal and Financial Services, Nuclear Consultancy Services as well as Engineering and Design Services (see Fig 24)

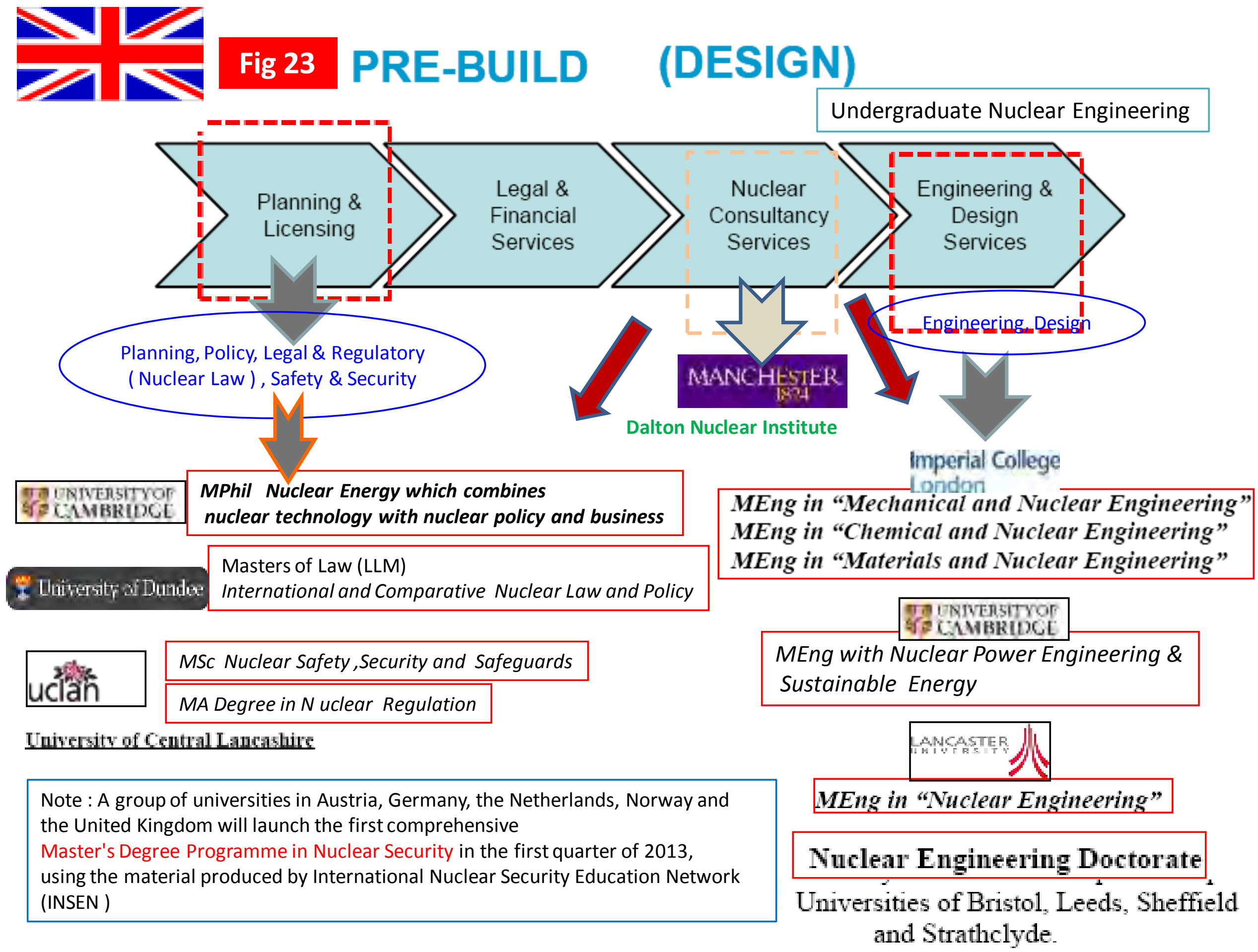


Fig 23 . Nuclear Courses offered in the UK which support Pre-Build Stage

b)Construction Stage

With reference to the Construction Stage , several universities in the United Kingdom offer courses covering Project Management, Building & Construction, Plant & Equipment, On site Erection (Fabrication), Nuclear Fuel Supply and Commissioning (see Fig 24a-Fig 24e)

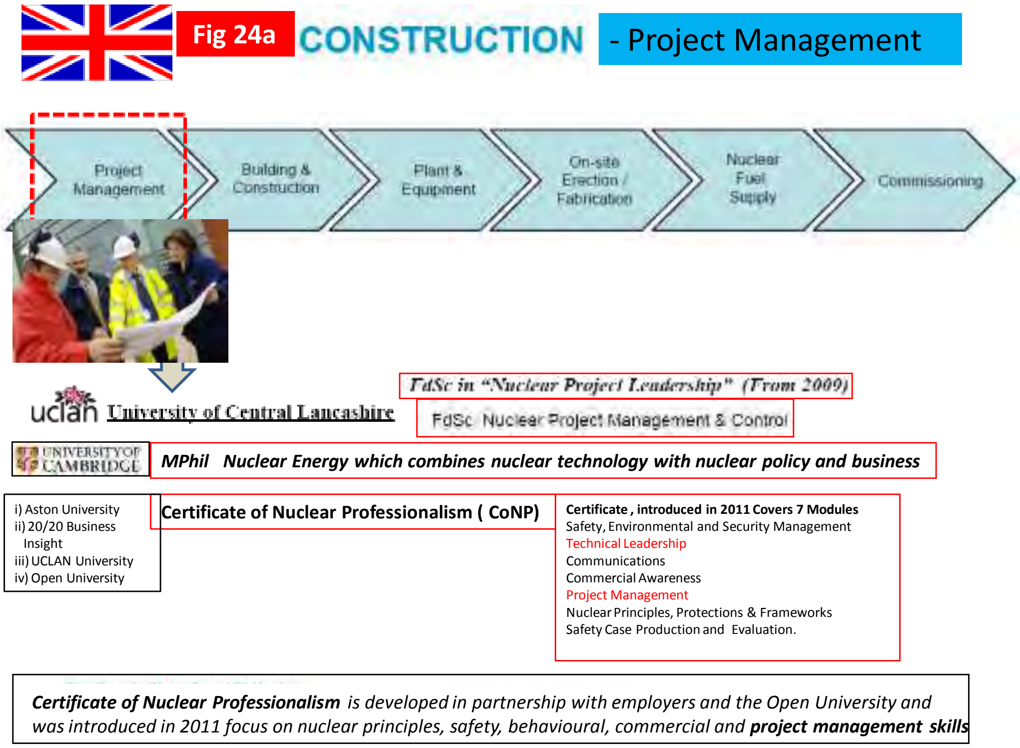


Fig 24a . Nuclear Courses offered in the UK which supports Construction Stage - Project Management

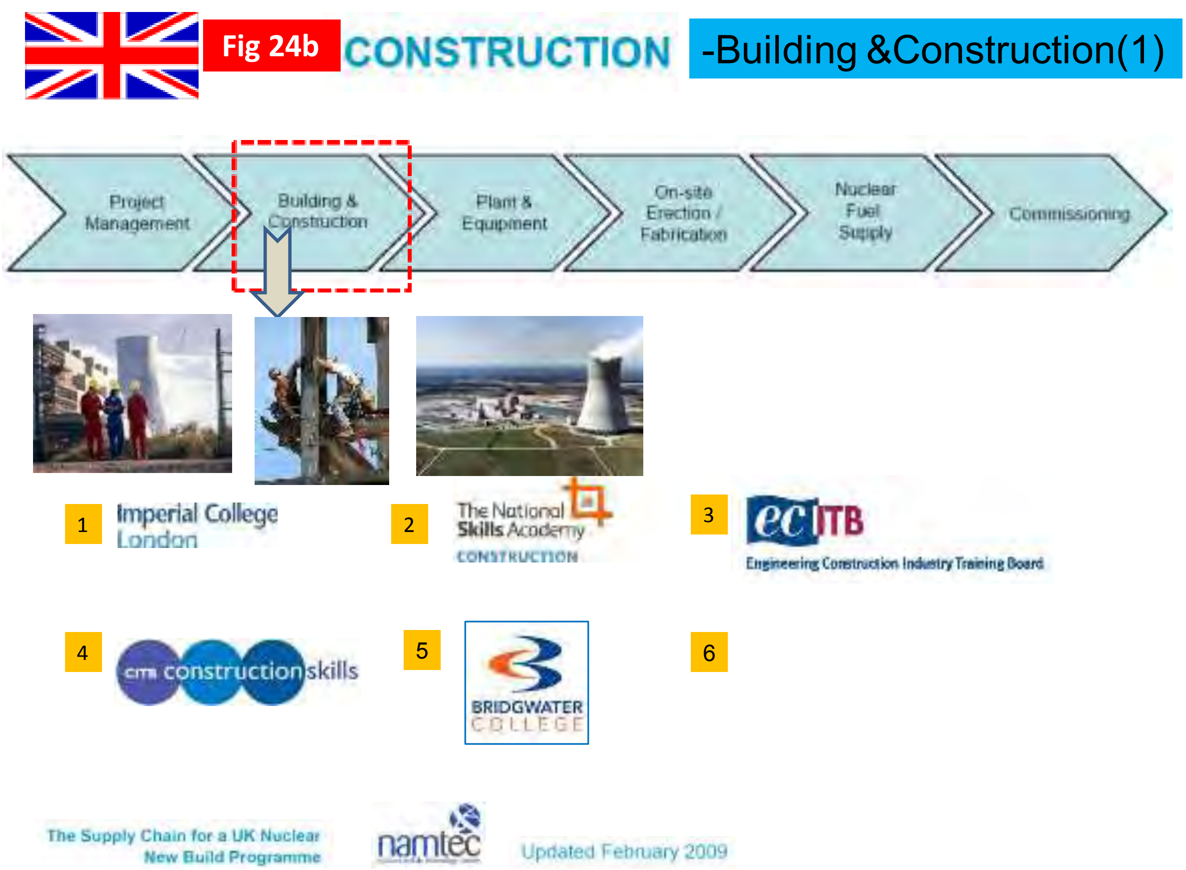


Fig 24b. Nuclear Courses offered in the UK which supports Construction Stage - Building & Construction

Fig 24c CONSTRUCTION -Building &Construction(2)

Nuclear Island

Photo source: Clive Smith Strategy Director Nuclear COGENT SSC:

Programme launched in 15 June 2011 for engineering students to have hands-on experience in designing and constructing a scaled down nuclear power plant.

Students will be assessed on radiation protection, site licensing, budgetary control and project management

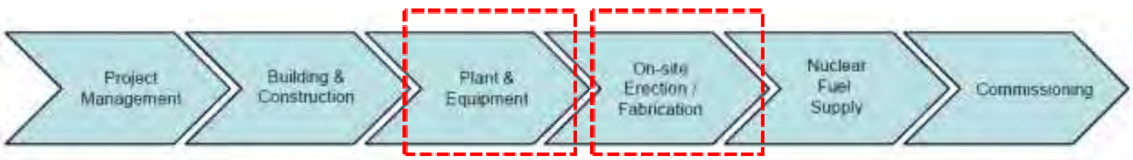
The Nuclear Island has been developed by a partnership of :
- Imperial College London,
- Constructionarium,
- Cogent Sector Skills Council,
- Engineering Construction Industry Training Board (ECITB) and
- Construction Skills.

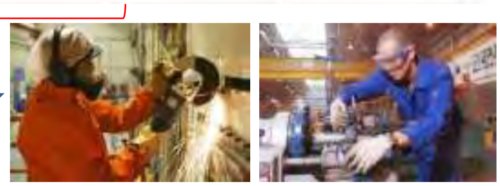
The partnership received funding to develop the project from the National Higher Education Science, Technology, Engineering and Mathematics (HE STEM) Programme and the Royal Academy of Engineers.

The Supply Chain for a UK Nuclear New Build Programme namtec Updated February 2009

Fig 24c. Nuclear Courses offered in the UK which supports Construction Stage - Building & Construction

Fig 24d NUCLEAR MANUFACTURING & FABRICATION – Part 1





1 The University Of Sheffield. MANCHESTER 1824 The University of Manchester Dalton Nuclear Institute

New Nuclear Build and Manufacturing (NNUMAN) programme has been awarded £4m funding by the Engineering and Physical Sciences Research Council (EPSRC) to research for new, innovative and efficient manufacturing technologies to enable UK manufacturing companies to learn the benefits of the new methods and apply them to new nuclear power plants

2 NUCLEAR AMRC

Nuclear Advance Manufacturing Research Centre

The most improved manufacturing processes developed in NNUMAN will be taken forward to prototype by Nuclear AMRC to enable UK manufacturing companies to learn the benefits of the new methods and use them to enable consortium members to become the suppliers of choice to the global nuclear industry

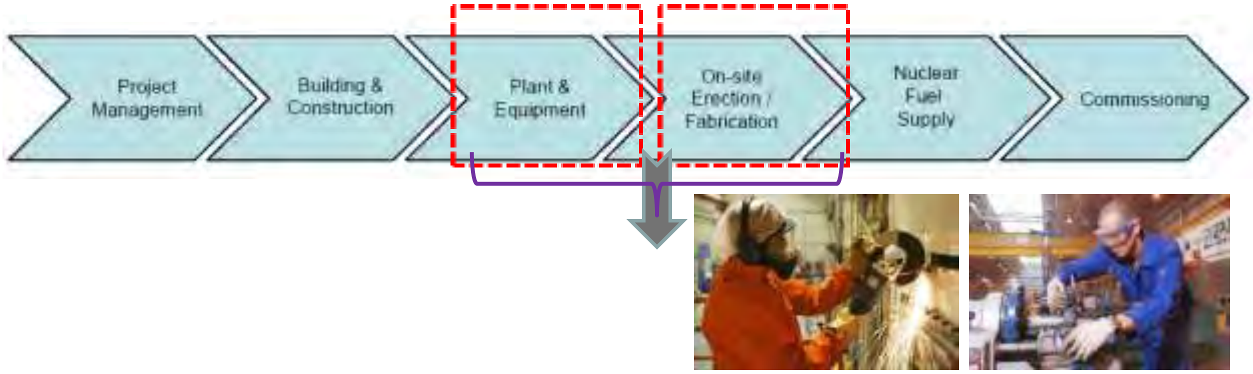
3 **National Skills Academy Nuclear – Manufacturing; a tri-partite collaboration between :**

The Su The National Skills Academy Nuclear semta NUCLEAR AMRC

A one stop shop for skills for nuclear manufacturing & further development of key training courses and qualifications to support the up-skilling of manufacturers

Fig 24d . Nuclear Courses offered in the UK which supports Construction Stage – Plant & Equipment Manufacturing

Fig 24e NUCLEAR MANUFACTURING & FABRICATION (Part 2)



The National Skills Academy Nuclear - Manufacturing is a collaboration between the National Skills Academy for Nuclear, Semta (Sector Skills Council for the Advanced Manufacturing and Engineering sectors) and the NAMRC.

A collaboration between:

The National Skills Academy Nuclear · semta · NUCLEAR AMRC

In addition, the dedicated manufacturing team will also look at ways of addressing the most critical technical skills shortages identified in the manufacturing segment of the nuclear supply chain, such as:

- Project Management
- High Integrity Welding
- Control and Instrumentation
- Planning and Estimating
- Non-Destructive Engineering
- Manufacturing and Design Engineering

The collaboration will work together to provide:

A one stop shop for skills for nuclear manufacturing.
High Quality Provider Network
Innovative support tools
Further development of key training courses and qualifications to support the up-skilling of manufacturers.

The Supply Chain for a UK Nuclear New Build Programme · namtec · Updated February 2009

Fig 24e . Nuclear Courses offered in the UK which supports Construction Stage – Plant & Equipment Manufacturing

b) Operation Stage

With reference to the Operation Stage , several universities in the United Kingdom offer courses covering Operation & Site Management, Nucelar Fuel Supply, Engineering/Technical Services and Waste Management & Disposal (see Fig 25a-Fig 25b)

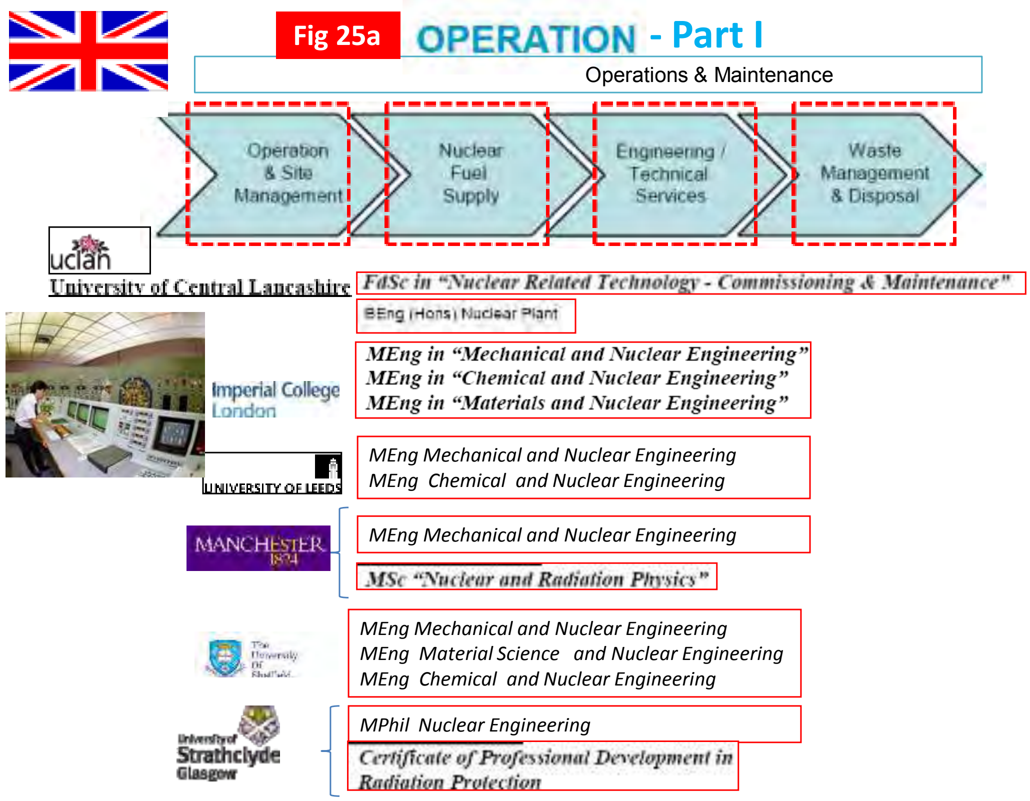


Fig25a. Nuclear Courses offered in the UK which supports Operation Stage

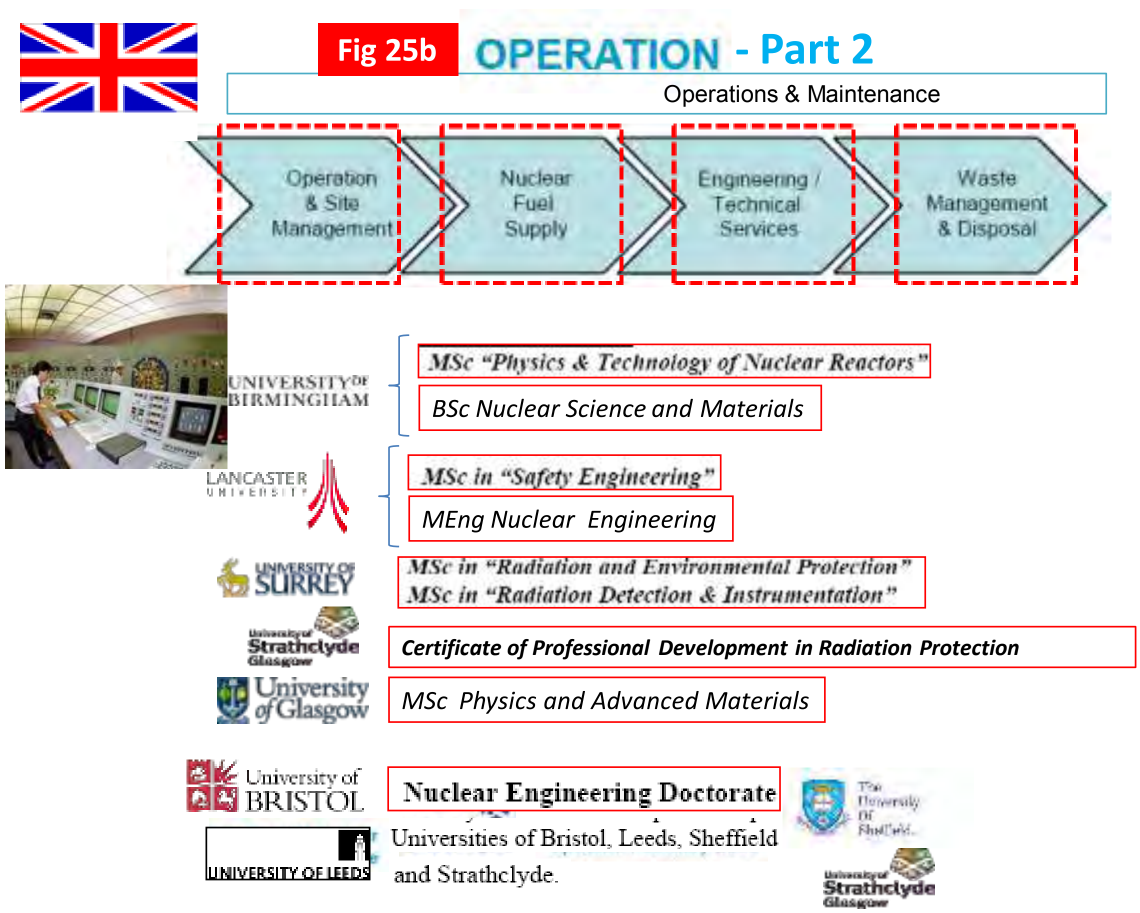


Fig25b. Nuclear Courses offered in the UK which supports Operation Stage

d) Decommissioning Stage

With reference to the Decommissioning Stage , Several universities in the United Kingdom offer courses to support work required for this stage (see Fig 26)

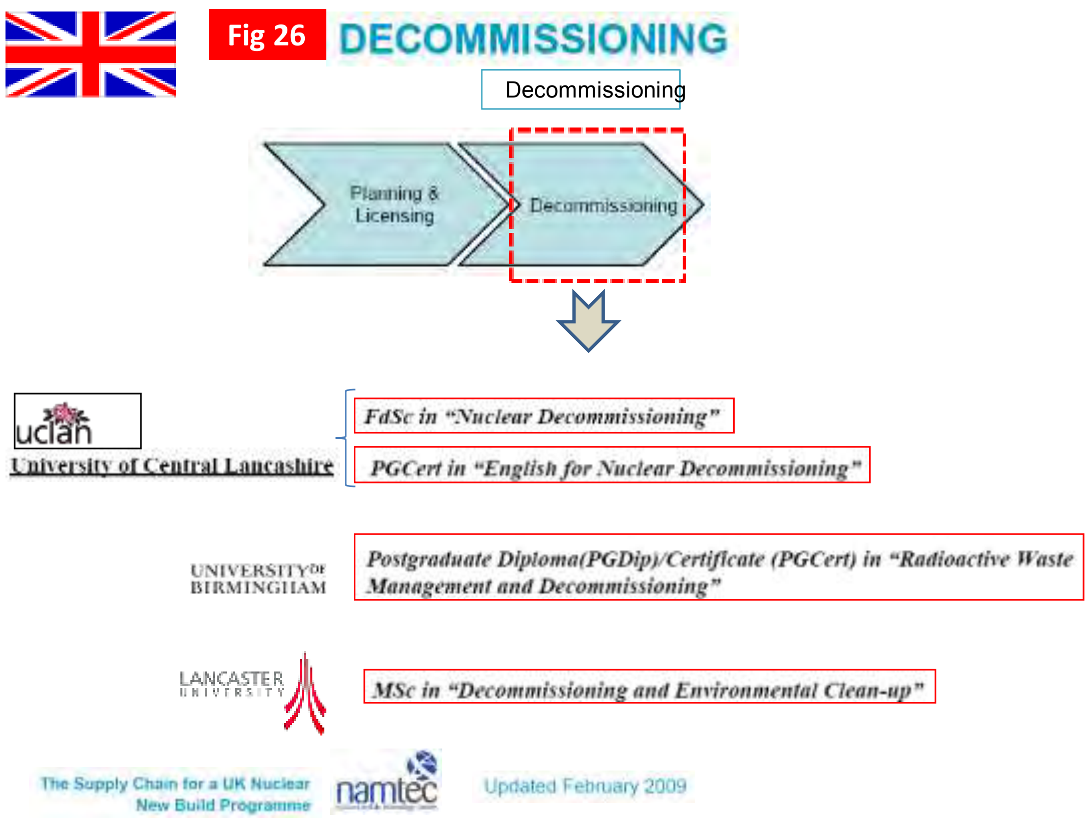


Fig 26. Nuclear Courses offered in the UK which supports Decommissioning Stage

UK Universities forming a Consortia to offer Post graduate Nuclear courses as well as Professional Development Courses (PDC)

A consortia of UK universities – NTEC (Nuclear Technology Education Consortium) and other institutions are providing postgraduate education in Nuclear Science & Technology as well as CPD (Continuing Professional Development) courses (see Fig 27a-Fig 27c)

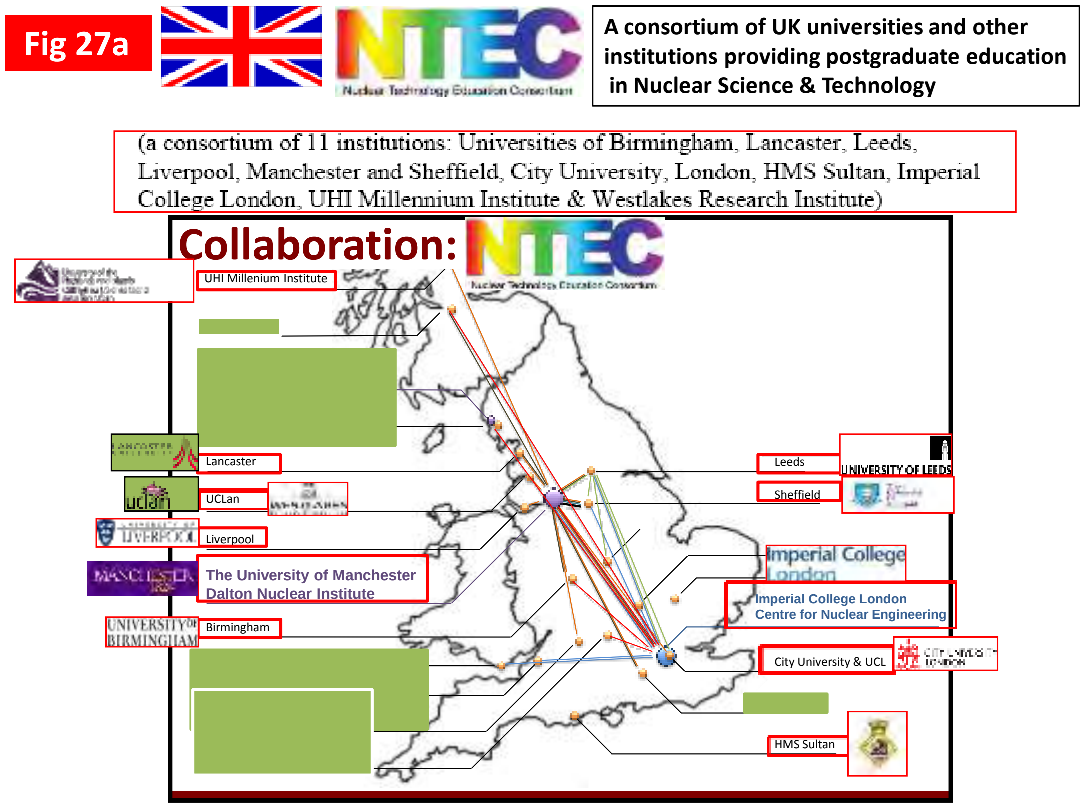


Fig 27a. NTEC providing postgraduate education in Nuclear Science & Technology as well as CPD courses

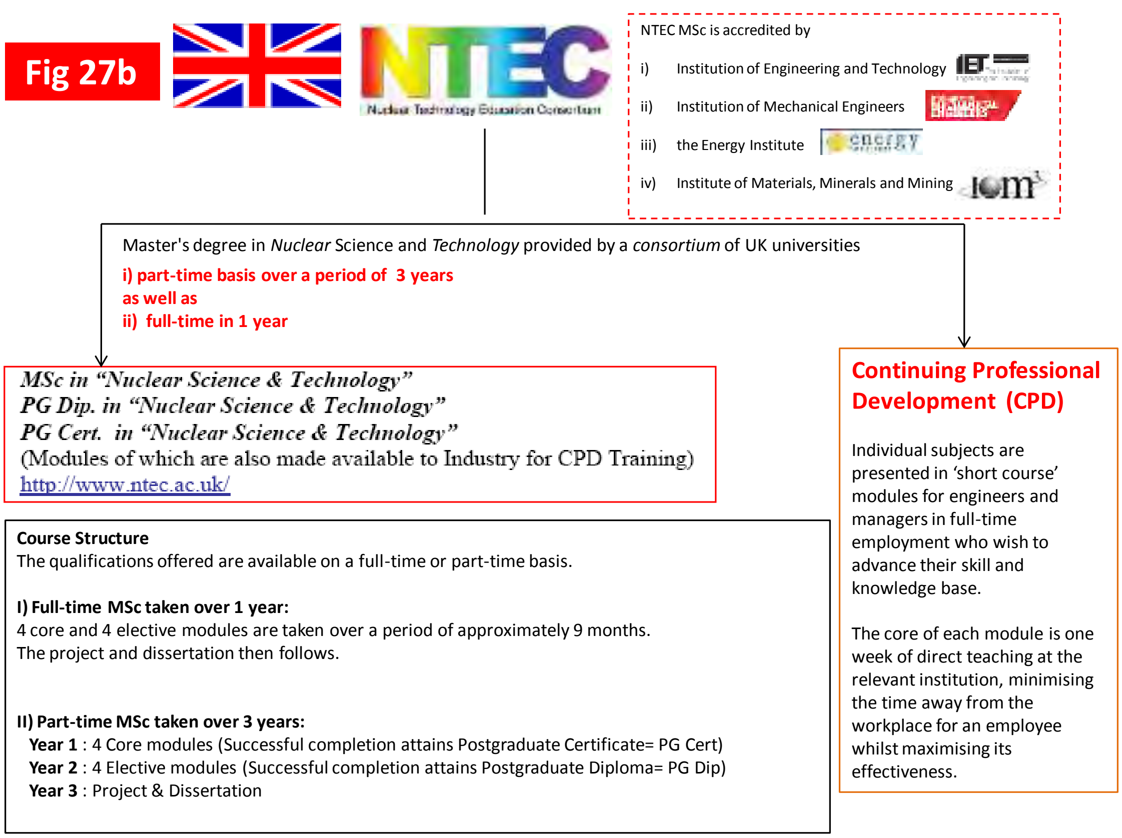
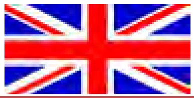


Fig 27b. NTEC providing postgraduate education in Nuclear Science & Technology as well as CPD courses

Fig 27c



One –week CPD Courses

Module Number	Module Title	Venue
N03*	Radiation & Radiological Protection	Manchester
N04*	Decommissioning, Waste, Environmental Management	UCLan
N23	Radiological Environmental Impact Assessment	Manchester
N12	Reactor Thermal Hydraulics	Manchester
N06	Reactor Materials & Lifetime Behaviour	Manchester
N09	Policy, Regulation & Licensing	Manchester
N21	Geological Disposal of Radioactive Waste	UCLan
N01*	Reactor Physics, Criticality & Design	Birmingham
N32	Experimental Reactor Physics - 2nd year Part Timers	Prague
N10*	Processing, Storage & Disposal of Nuclear Waste	Sheffield
N08	Particle & Colloid Engineering in the Nuclear Industry	Leeds
N02*	Nuclear Fuel Cycle	UCLan
N05	Water Reactor Performance & Safety	Imperial
N11	Radiation Shielding	Liverpool
N31*	Management of the Decommissioning Process	Birmingham
N13*	Criticality Safety Management	Manchester
N29*	Decommissioning Technology & Robotics	Lancaster
N07	Nuclear Safety Case Development	Manchester
N14	Risk Management	City
N32	Experimental Reactor Physics - Full Timers	Vienna

Fig 27c. NTEC providing postgraduate education in Nuclear Science & Technology as well as CPD courses

11. Recommendations

1. **Set up a Task Force on Nuclear Education & Training , could be chaired by Minister of Education with membership of all Nuclear HRD stakeholders**

   Invite Universities, Industry, Government Agencies & Others to sit & talk TOGETHER on the way forward for Nuclear Education &Training

   Partnership or Consortium may be established for offering Degree courses ,Continuing Professional Development (CPD) courses may refer to IAEA , MIT and UK Best Practices
   - Avoid Duplication & Competition (resources wasted-people, time & money!!!)

2. Identify Nuclear Education & Training Needs for stakeholders:

eg a)Government – Planning/ Policy/Governance/ Risk/ Export Control
b) Industry – Business opportunities: manufacturing, construction engineering etc
c) Regulatory body- Law & Regulation
d) Academia & R&D Agencies – Nuclear S&T, R&D

3. Critical to remember – Manpower trained is NOT JUST to work in a nuclear power plant or station but in other organizations in the nuclear power sector value-chain eg Government, Industry, Businesses, Media, Finance etc

4. Prepare Nuclear HRD Roadmap to outlining areas/fields/ number of personnel/ timeframe/funds required

5. . **It may not be strategic for a number of universities to be offering same or similar courses on nuclear engineering**

It may be more relevant for each university to identify its strengths and then offer the selected courses to support nuclear power

eg *University A offers Nuclear Engineering*
University B offers Nuclear Safety and Security
University C offers Nuclear Law and Policy
University D offers Nuclear Energy incorporating Business

6.For institutions currently offering only Nuclear Engineering courses it may be relevant to introduce other related courses- independently or as part of an existing module **covering Nuclear Energy, Law, Governance , Risk , Business, Finance, Economics etc**

7. Apart from the offer of Nuclear Engineering courses for undergraduates/ graduates, institutions of Higher Education as well as private E&T Centres could **consider also offering courses to:**

a) Working professionals
b) Technicians
c) Craftsmen

8. **In view of the great importance of public opinion and the significant role of the media must be given due recognition.**

   - Open/ Introduce & offer Nuclear Education & Training to Media representatives

   i) Develop specialized topics/curriculum to encourage media participation and

   ii) consider inviting foreign media to share their views and experiences on nuclear power with local media and the general public

9. As Financing is amongst the critical factors for Nuclear Power Projects to be realistically implemented,

   - Open/ Introduce & offer Nuclear Education & Training to representatives from the Banking & Financial Sector

   i) Develop specialized topics/curriculum for financiers and

   ii) consider foreign investors in NPP to share their views & experiences

10. As Nuclear Leadership is fundamental to ensure the safe, secure and safe operation of nuclear power plants (to the NP plant owners as well as national economy) **relevant Nuclear E&T Agencies/ organizations (including the IAEA/WNA/WNU NEA/OECD and others including European Nuclear Society (ENS) could consider introducing**

    a) Nuclear Training Programmes (short courses) for Nuclear Leaders covering :

    i) Politicians
    ii) Policy and Decision Makers
    iii) Senior Management of Nuclear Power Plants
    iv) CEOs of Nuclear Businesses

    in place of ENEL which had closed down.

    [Note: As the World Nuclear University (WNU) 's 6 weeks summer course targets young professionals up to the age of 40 years the Nuclear Leadership course could cover Politicians, Policy & decision makers as well as Professionals above 40 years who are given leadership roles in Nuclear related initiatives/organizations/Ministries/Cabinet]

    b) also for Financial & banking sector Officials as well as
    c) Media Representatives

11. Recommendations for enhancing cooperation in nuclear education and training aimed at building synergy amongst the international member countries

Presently there are a number of Nuclear Education and Training Networks covering the Global Level, Regional Level as well as National Level (see Fig 28).

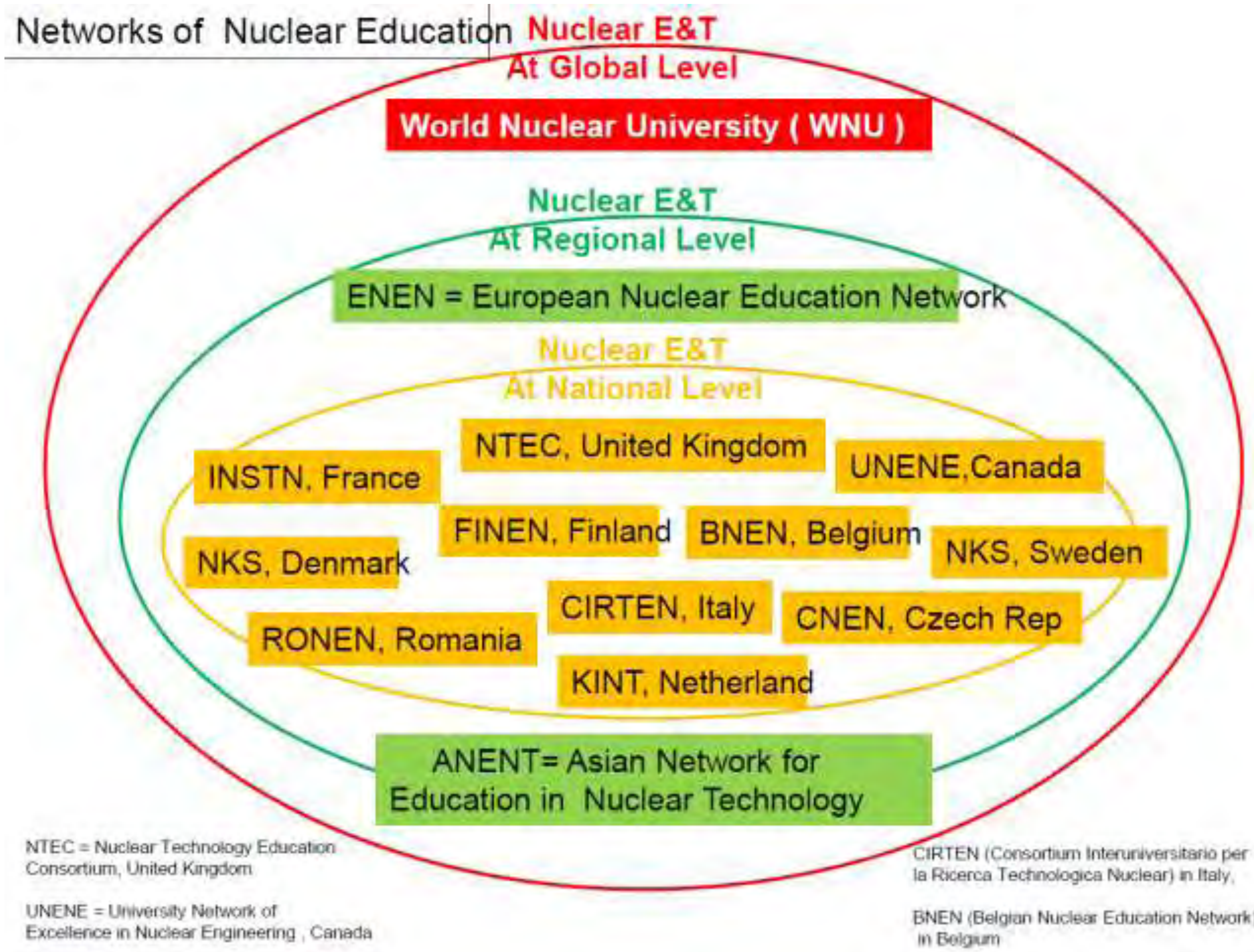


Fig 28: Networks of Nuclear Education at Global, Regional and National Levels

i) Countries planning for the introduction and implementation of NPP are recommended to review the Nuclear Education and Training Best practices offered at the Global level by the World Nuclear University (WNU), at the regional level such as that offered by ENEN and ANENT as well as specific programs provided at national level including INSTN in France, NTEC in the UK, FINEN in Finland and NKS in Sweden amongst others , to use as strategic inputs for the formulation of local /national Nuclear E&T within the country. Relevant and related syllabus and courses can be adopted and adapted for specific country –use and introduction.

ii) In cases where it may not be beneficial for countries to introduce particular courses due to lack of resources and critical mass, these countries may wish to establish partnerships and cooperation with the global , regional and national Nuclear E&T networks to harness the currently available expertise and resources

12. European Nuclear Society (ENS) can take the initiative and lead to prepare a softcopy and hardcopy Directory of Nuclear Education and Training offered by EU Member States covering all stakeholders including:

i) Politicians

ii) Policy and Decision Makers

iii) Professionals with Potential to be Nuclear Leaders

iv) Other Working Professionals

v) Business Leaders and Industry Representatives including the Financial and Banking Sector

vi) Students

vii) Technicians

viii) Craftsmen

ix) Public and

x) Media Representatives

And I would be happy to offer my support and ideas to the ENS for this initiative

LEARNING READILY: HOW CAN LEARNING IN FLOW BE PROMOTED THROUGH WEB-BASED TRAINING?

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ABSTRACT

"Anyone who makes a distinction between games and education clearly does not know the first thing about either one."[1]
Learning is exhausting and demands a high level of discipline: the fruits are always only noticeable later. However how would it be if we were to learn readily and if we were to succeed with learning so effortlessly, that it gave us joy and would bring fulfillment?
However the credo that learning is associated with hard work is very deep-seated in the German education system, and has to be revealed sooner or later as a hindrance to success. To acquire something new, it should involve the joy and pleasure of creative work; such is the assumption of a master thesis, which originated in 2015 as cooperation between the Friedrich-Alexander-University, Erlangen-Nuremberg and the AREVA GmbH Erlangen.
This attitude also reflects the current trend in the field of learning with digital media. Learning is more and more frequently connected with its experiential and entertainment value.
However, how can the joy of learning and its effectiveness be promoted?
Regarding this the paper introduces the learning theories of flow and of constructivism, plus a set of criteria based on that, as an approach to promoting learning. Furthermore the results of applying the criteria to some web-based training courses already in use at AREVA will be illustrated and discussed based on practical visual examples.

1. E-Learning, Web-Based Training

Caused by the world wide accelerating process for knowledge digitalization and its provision on digital media that are accessible via networks by almost everybody, more and more of these digital media have taken on the role of knowledge facilitators. Consequently, traditional face-to-face learning in formal environments like colleges, universities, or training centers has been enhanced considerably or even replaced for several years already by e-learning.

As stated e.g. by the FAO[2], "E-learning can be defined as the use of computer and Internet technologies to deliver a broad array of solutions to enable learning and improve perfor-

[1] Marshall McLuhan

mance.[3]" In the specific format of web-based training (WBT), e-learning is implemented in well-specified formal courses that can be accessed and worked through by the learners via an Internet or Intranet connection. Additionally, communication between the learners and the trainers or experts can easily be facilitated in different ways. Learning can thereby be supported as a social process where the interaction between the different participants as well as tutors could contribute effectively to achieving the learning objectives.

2. How to boost learning processes by e-learning?

Different issues have already been dealt with in the public or pedagogical discussion about benefits or disadvantages of the use of e-learning. However, a consensus has been reached: complementing traditional learning paths by including e-learning (called blended learning) has always been beneficial for achieving the learning objectives.

Nonetheless, in the past the discussion has focused more on issues like means of capturing and presenting knowledge (e.g. by text, graphics, audio, video), means to develop skills (animation, simulation, in particular in connection with Virtual or Augmented Reality), or means how to develop efficiently e-learning, e.g. the appropriate development tools or a programming environment providing all necessary tools.

Recently, a specific format of capturing and delivering knowledge to a large public audience, namely Massive Online Open Courses (MOOCs), has gained much attention. In this format, lectures given by a successful or gifted instructor are often recorded as video, and the video subsequently broadcasted via the Internet to a large audience.

So far, however, in the discussions a topic has been neglected that focuses on the essential basic question from a learner’s point of view: how can it be ensured that people are able to learn easily? What success factors should be taken into account when developing e-learning, beyond a set of recommendations like including interesting and exciting videos? What do learning theories provide as answers to these questions, in particular how can effective recommendations be derived from basic assumptions on how people learn easily and successful?

3. E-learning for company internal training

Talking of internal training within a company, the main purpose is to further develop the competences of their employees, either for new recruits to raise their competences to the job-specific required level, or to adapt the competences of employees to changing conditions in their job positions, caused either by external or internal developments. The final aim is to align competences of human resources with the specific internal or external requirements of their job positions (which themselves are shaped by the specific conditions in a particular industrial environment).

Often, competence development is not well designed and developed, and in many cases implemented by informal on-the-job training. However, when dedicated training is developed and appropriately designed by specifying (e.g.) target groups, their pre-requisites, training objectives and training methods, the effectiveness of this training may be enhanced considerably, and even measured on several levels (see [2], e.g.). Nevertheless, this formal approach may become pricey, not only because of training development costs, but also because of the trainees’ time to be charged for attending the courses.

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[2] United Nations Food and Agriculture Organization

[3] See GHIRARDINI 2011, http://www.fao.org/docrep/015/i2516e/i2516e.pdf

Here, e-learning seems to offer some cost benefits: it can be used only when needed, and more or less independent of time and location, even outside working hours. Consequently, within AREVA, a supplier of nuclear plants and related services with about 40,000 employees worldwide, e-learning in the format of web-based training meanwhile is already a consolidated part of company internal training.

In the context of the nuclear industry, however, with its stringent demand for well-qualified and motivated human resources, it is very important to know to what extent these new learning formats will contribute to effective education and training – do the trainees really learn what they are supposed to learn?

Clearly, a structured process to design, develop and implement training as prescribed by the Systematic Approach to Training (see [3]) will play an important part with regard to training effectiveness. But the question remains: how to support learning in Web-Based-Training in an optimal way? Therefore, when focusing on the learner's point of view, in addition to applying SAT process, it will be very rewarding to investigate which training methods will assist in achieving learning effectiveness.

4. Factors to strengthen learning effectiveness: flow theory

Starting with flow theory: here, as mainly represented by Mihály Csíkszentmihályi (e.g. see [1]), a state of flow means "a state of concentration or complete absorption with the activity at hand". Or: "The flow state is an optimal state of intrinsic motivation, where the person is fully immersed in what he is doing".

According to flow theory, to arrive in a flow state means that seven basic states of mind have to be achieved, namely

1. Being completely involved in what we are doing - we are focused, concentrated
2. Feeling a sense of ecstasy – we are outside everyday reality
3. Getting great inner clarity – we know what needs to be done, and how well we are doing
4. Knowing that the activity is doable – that our skills are adequate to the task
5. Establishing a sense of serenity – no worries about oneself, and a feeling of growing beyond the boundaries of the ego
6. Staying timeless – thoroughly focused on the present, hours seem to pass by in minutes
7. Being intrinsically motivated – whatever produces flow becomes its own reward.

In this sense, a state of flow describes a situation in which a person is highly concentrated. You are not aware of time while being completely satisfied practicing a certain activity. This aspect of easiness can be imagined in relation to the excited play of a child that then casually learns a lot of things.

Consequently, when a particular learning environment allows the learner to arrive in a state of flow, with a feeling of joy and effortlessness the learner should become engaged and adapt to his or her personal needs and proficiency level - an ideal precondition for effective learning. But how can a state of flow be achieved while implementing digital media, in particular in the format of web-based training? How to attract the learner's attention, or how to support concentration?

These are the questions that have been considered during work on the Masters thesis. The results will be shown in chapter 6 – questions to check that should be applied already in an early phase of WBT development, to ensure that the WBT really supports arriving in a state of flow.

5. Factors to strengthen learning effectiveness: constructivist learning theory

Different learning theories exist that attempt to prescribe how to support learning optimally in order to achieve the required competence development. After behavioristic and cognitive theory, in past years the constructivist learning theory has become widely applied (e.g. see [4]).

According to this theory, learners construct their competences individually, yet anchored in a social context. This means that they initiate their skills development process by themselves; they organize and structure the material that they have received via their learning environment and communicate with others in order to draw their appropriate conclusions. The newly acquired skills will be linked to the existing ones, and will lead to a continuous competence growth, enabling the learners to act according to their skills level. Furthermore, problem-oriented learning (using relevant or authentic problems or situations) will connect the learners directly with their learning activities.

In summary, focus is laid on the learner's point of view in regards to their learning activity. What are the conclusions in the context of WBT to be deployed for company internal training?

First of all, the contents have to be really relevant for the daily challenges of an employee. Furthermore it should adapt to the individual interests of the learner and give him the freedom to decide about what he wants to learn at which time and in which intensity. Besides, an e-learning based on the theory of constructivism has to provide variegated types of knowledge and views with different approaches so that the learner is challenged to form their own opinion. And the way the contents that are presented should motivate and bring the learner into action, too.

Another aspect of the constructivist perspective is to integrate social learning processes and feedback into WBT. The learner needs to share ideas and even difficulties with other people, who go along with them.

6. Requirements and criteria

As a conclusion from dealing with flow theory and constructivist learning theory, the following requirements must be fulfilled in order to optimally support learning:

Theory	Requirements
Flow	- acceptance and motivation - concentration - clear learning objectives - unambiguous operation procedure - optimal degree of challenge - direct feedback
Constructivist	- authentic problem - decision making and responsibility of control - adaptation to the individual interests - broad information offer from different perspectives - activation - communication

Table 1 Requirements for optimal learning support

Optimally in the sense that employees should be enabled to learn readily and to succeed with learning so effortlessly, that it would give them joy and would bring fulfillment, i.e. to acquire something new, learning should involve the pleasure of creative work.

In the next step, by regrouping the requirements we then developed several criteria based on them that could finally be used to evaluate web-based training courses. Here, we focused more on a simple model of user interaction within the usual office environment of an AREVA employee, without investigating in too much detail the media theoretical aspects of the user interface implemented in the WBTs to be evaluated.

Criteria groups	Questions to check
Motivation	a) Is the topic based on everyday life and useful? b) Are avatars used, is a framework history provided or will the learner be addressed in any personal form? c) Can the WBT be adapted to the prerequisite knowledge and interests of the learner?
Activation	d) Are learning objectives specified at the start of WBT? e) Are interactive, game-like elements used such as quizzes, correlation tasks or puzzles? f) Does the WBT think outside the box: is there additional information or any recommended reading given?
Concentration	g) Is the WBT clearly arranged? h) Does the WBT positively provoke excitement or is it immersive?
Communication	i) Is help provided for formal or content-related questions? j) When working with problems, is direct and extensive feedback provided? k) Is synchronous communication provided for exchange with experts or other learners about the content?

Table 2 Criteria to check optimal learning support

To ease the application of the checklist when working with the WBTs, the results as to whether the respective criteria have been fulfilled are presented in numerical values 1 – 5, with 1 given when the respective criterion has been completely fulfilled.

7. Results of evaluation of e-learning courses

Next, these criteria were applied to 3 courses that already have been implemented at AREVA for different target groups and training objectives.

First, the WBT Introduction to Business Process Management was reviewed with our criteria. This WBT is directed towards all AREVA employees that have to deal with business processes. It further serves to introduce the learners to a tool supporting business process management. In this WBT, the criterion Concentration has been well fulfilled, mainly due to the plain layout, the clearly arranged structure and the use of video clips. Furthermore, the usefulness and authenticity of the topic, the use of an avatar to ease the monotony and the personal addressing of the learner support the learner's motivation well. However, the learner is not well engaged, as there is not as much room to maneuver, with only a restricted use of interactive elements.

Next, the WBT Valves and Actuators for Nuclear Applications was reviewed. The target group is restricted to engineers dealing with component design or procurement, and, here in particular, aims at new recruits to introduce them effectively into nuclear applications of valves and actuators. Here, the great strength of this WBT is fulfilling the activation criterion well, in particular by providing a lot of diverse interactive elements. Furthermore, the authentic theme, as well as the possibility of adapting the content to the previous knowledge and interests of the learner, effectively supports motivation and concentration. However, with regard to communication, the scope of feedback and its relation to learning topics could be further improved. Furthermore, no synchronous communication possibilities are provided.

Finally, the WBT The Kraftwerk-Kennzeichen-System (KKS) was reviewed by applying our criteria. Here, motivation is well developed, caused by its integration in blended learning, and by the possibility to adapt the content to the previous knowledge and interests of the learner. However, by relying more on text and only some graphics media, without any audio or video, and without many interactive elements, engaging the learner is only partially achieved. Furthermore, a better, clearer arrangement (format, layout, structure) of learning content while not relying too much on text would greatly support the concentration of the learner. With regard to communication, synchronous communication is also not provided here, whereas feedback for working with problems is given in the appropriate scope.

In summary, these three WBTs exhibit different ways to comply with the criteria listed above. Some criteria are well fulfilled, at least to some extent, whereas others are only partially achieved. In all WBTs, synchronous communication is not provided, thereby missing the chance for the learners to exchange with other learners or tutors. However, all WBTs clearly motivate the learner by providing a meaning and authenticity of their content. In total, no WBT can be regarded as an ideal implementation of all requirements that support the effectiveness of learning from a learner's point of view.

8. Three simple Examples

Two positive examples for an interactive task (fulfilling well the criterion e):

One negative example as feedback: the learner only receives the information as right or wrong. It would be better to insert a link to the information that is necessary to solve the problem.

9. Conclusions and recommendations

The investigation has shown that factors that support the effectiveness of learning are apparently not well-known and not systematically applied in the training development process. Consequently, the success of training by e-learning depends to a great extent on the competence of external suppliers for e-learning development (i.e. programming).

Considering these factors at an early stage of training, development would greatly enhance the efficiency of the process as a whole. Consequently, they must be made public, and the people responsible for designing and developing training, i.e. e-learning, must become familiar with them. For this purpose the criteria list as shown above should be applied at the latest when designing training, in particular for designing e-learning. This will not only allow for cost effective development and implementation (with detailed specifications for e-learning programming by external sub-contractors), but also for effective learning by people from the training target group. In summary, this will essentially contribute to the success of web-based training.

When considering the future of learning that is supported by digital media, it can be observed that social, cooperative and multimedia learning with integration of game-based and interactive elements will gain more and more importance. In the nuclear industry, within a nuclear safety culture that implies continuous competence development, these elements will have to be carefully selected. The final goal will always be to develop all required competences of the human resources in nuclear industry in order to guarantee the highest level of nuclear safety and operational excellence.

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LONG-TERM OPERATION OF THE SWEDISH CENTRE FOR NUCLEAR TECHNOLOGY (SKC): NEW CHALLENGES AND SOLUTIONS IN COMPETENCE BUILDING!"

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ABSTRACT

The Swedish Centre for Nuclear Technology (Svenskt Kärntekniskt Centrum, SKC) is a national initiative to perform industry-relevant research at Swedish universities, and to support dedicated education of direct use to the Swedish nuclear industry.
SKC has been the meeting point between industry and academia for almost 25 years, and has coped with varying needs from industry and political situations. The present situation in the Nordic countries is split: Sweden plans to shut down four out of ten reactors by 2020, while Finland is planning and constructing new reactors. Even without a strong signal to construct new reactors in Sweden, the need for nuclear competence will stay, as we have challenges in front of us to operate and dismantle power plants, operate the intermediate storage facility CLAB in Oskarshamn, and to build and fill the final repositories in Forsmark.
The education supported by the SKC at the selected universities will facilitate possible recruitment for nuclear installations. The funding body of SKC consists of all the Swedish Nuclear Power Plants (NPP) situated in Forsmark (three BWRs), Oskarshamn (three BWRs) and Ringhals (one BWR and three PWRs), and the nuclear fuel manufacturer (Westinghouse), while the main research and education is carried out at Chalmers University of Technology, KTH Royal Institute of Technology and Uppsala University with corresponding in-kind contribution. The research activities cover highly requested studies for today's nuclear fleet: material embrittlement, stress-corrosion cracking, accident-tolerant fuel development and ageing management for long-term operation (LTO), while the educational part consists of Bachelor and Master programs as well as elective courses for students outside the main nuclear programs and contract education.

In the Master programs, focus is on E-learning platforms for courses and examination. Another success story is project-based courses in industry, especially within the Bachelor programs. This is highly appreciated by students, providing a direct contact with future employers,

The success of SKC originates from close contact between the funding bodies and academia on many levels: funding for course preparation, project-support through annual calls, and dedicated long-term research funding. There is also an exchange with industrial dedicated experts, and an enthusiasm from academia to enlighten present research issues, as well as strong presence at universities during student fairs and career days. That is LTO of SKC!

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1. Introduction

The Swedish Centre for Nuclear Technology (SKC) is where industry meets academia to solve present research issues as well as improving and performing education in the field [1]. SKC supports education and research in disciplines applicable to nuclear technology. The education program is also supported by financial contributions to senior positions at the universities. Research funding is given to three research programs:

- Nuclear Power Plant (NPP) Technology and Safety
- Reactor Physics and Nuclear Power Plant Thermal Hydraulics
- Materials and Chemistry

SKC was established in 1992 to provide long-term support to securing knowledge and competence development at an academic level for the Swedish nuclear industry. The overall goals of SKC are:

- Increase interest among students to enter nuclear technology education.
- Enable the SKC financing partners to recruit qualified personnel with a nuclear technology education.
- Offer attractive education in the nuclear technology area.
- Maintain strong and internationally acknowledged research groups within areas that are vital for and unique to the nuclear technology area.
- Create organizations and skills at the universities such that research can be performed on account of the financers of the SKC also outside the boundaries of the SKC agreement.

The Swedish nuclear industry consists mainly of the NPPs situated in Forsmark, Oskarshamn and Ringhals, with in total 10 reactors in operation. In addition to these three plants, the nuclear fuel manufacturer Westinghouse Electric Sweden situated in Västerås, is also part of SKC. These four partners are funding Ph.D. students, specific research projects, and development tools in education at Chalmers University of Technology (Chalmers), the Royal Institute of Technology (KTH), and Uppsala University (UU).

Fig 1. Collaboration between industrial and academic partners within the Swedish centre for Nuclear Technology (SKC).

SKC research include material ageing and fuel studies, such as projects on Accident Tolerant Fuels, material microstructure changes with respect to ageing, and processes during normal and transient conditions which affect the ageing or fuel.

In order to provide an incentive for students on all levels to pursue nuclear engineering education, SKC annually awards the Sigvard Eklund Prize, in memory of the former IAEA Director General (1961-1981), for the best Ph.D. thesis and diploma works on the Master's and Bachelor's level with nuclear technology relevance. In 2015 the prize was awarded to Klara Insulander Björk and Cheuk Wah Lau at Chalmers for their work on the usage of thorium fuel in light water reactors. The prizes for best M.Sc. and B.Sc. theses were awarded to Giulio Imbalzano, KTH, and Johan Larsson, UU, for work on material modelling, and documentation of maintenance simulator training respectively.

SKC will continue serving as a bridge between universities and industry even in a time of structural changes and financial challenges. The aim now is to give the opportunity for SKC's financers to ensure the cooperation on the long-term, and to help providing knowledge for long-term operation (LTO) of the Swedish NPPs.

2. Challenges for nuclear engineers and needs for competence building

The SKC cooperation is aimed at contributing to a **safe, effective** and thus **reliable nuclear energy production**, which is an important part of the Swedish energy supply. Ensuring safety is the major prerequisite to achieve the goal of life time extension. One of the main challenges today and in the future is learning more about material ageing and degradation.

With a large power reserve, no (or low) increase in electric demand and low electricity prices, the economic challenges to be overcome by Swedish nuclear industry will continue to grow for a few more years. Another mayor challenge is how to keep a strong national nuclear competence to allow for continuous operation of the nuclear power plants. This will be of main focus in the near future.

Another issue is the changed focus in Sweden today from new build plans to decommissioning and nuclear waste management. The need for excellent nuclear engineers is challenging to explain to students on a declining market. However, the new areas also introduce new and exciting tasks, where new technologies and tools are needed.

Regarding education, several levels are needed to pursue the future need in the nuclear industry. Master programs at the universities are still very popular due to high quality and excellent international student exchange programs. An example is the top rating of the KTH M.Sc. program in Nuclear Engineering in a recent national assessment [2]. The classical courses are more and more given in the form of E-learning, which makes courses more accessible as well as easier to manage.

Since the early 2000s educational activities at Uppsala University have very successfully evolved along three lines, all with the primary objective of providing Swedish NPPs with engineering graduates and to provide already existing staff with continued education [3,4]:

- Introduction of nuclear technology courses within already existing engineering programs with specialisations in different subjects, e.g., engineering physics, energy systems and sociotechnical systems engineering. The objective is to expose as many students as possible to introductory nuclear technology courses.

- Introduction of contract education courses for the continued education and professional development of NPP staff. Some of the contract courses have been made available for UU engineering students and their participation in the contract courses has proved a huge success. Students, often for the first time during their education, get the opportunity to establish contacts with professionals within the nuclear industry and as a result of their participation, very often elect to perform their diploma work within the field. Also, the nuclear industry recognizes that participating students constitute a previously unavailable recruitment basis.
- As a result of the close cooperation between UU and industry a Bachelors' program in nuclear engineering was started 2006. The primary objective is to provide industry with engineering graduates that are well suited to be employed by the NPPs, preferably within operations and maintenance where industry had identified their biggest long-term need for new staff.

3. Educational programs

SKC funds education in the form of B.Sc., M.Sc. and Ph.D. studies at three different universities in Sweden. Uppsala University focuses on their B.Sc. program, as well as specific nuclear courses in the M.Sc. program in Energy Systems Engineering. Both Chalmers and KTH carry out M.Sc. programs in Nuclear Engineering. Chalmers is combining physics and chemistry in their educational program. KTH is also involved in the European M.Sc. program EMINE (European Master in Innovative Nuclear Energy Engineering) and offers dual M.Sc. diploma with other countries as well, such as Tsinghua University, Beijing and Korea Advanced Institute of Science and Technology, KAIST. The KTH M.Sc. program in Nuclear Engineering got the highest grade in a Swedish national assessment of all Master programs at Swedish universities in 2013 [2]. It should be noted that there is at present only a small but limited decline in student interest for Nuclear Engineering, which is helped by the high quality in the courses offered.

4. Future directions of SKC and Swedish nuclear education

The need for nuclear education in Sweden is still high, and will continue to be so for many years. However, the political and economic situation at present related to energy makes student hesitant to a future carrier in the nuclear business. In Sweden, several reactors are about to close within three years, and the nuclear fleet will be six reactors as compared to twelve in the late 1990s. Therefore a number of tools and ways forward have been suggested and launched. A few of these will be mentioned below.

4.1. Industrial involvement in courses

In all the mentioned educational programs above, several guest lecturers are invited to give lectures or presentations in some form. Chalmers invites for example lecturers from WANO (World Association of Nuclear Operators) for two days to talk about safety culture, R&D engineers at Vattenfall AB give lectures on thermal hydraulics at KTH and invite students to follow experiments in the Älvkarleby Research Laboratory (see Fig 2).

Fig 2. KTH Master students from the Nuclear Engineering program on visit in the Vattenfall Thermal Hydraulics Laboratory in Älvkarleby, where Johan Westin (right) shows a test facility for thermal mixing around a control rod.

In the KTH Master course “Safety Leadership in Nuclear Power Industry” expert guest lecturers from authorities and industry participate, such as from SSM, IAEA, Vattenfall and E.ON. The course is examined through group assignments, and presentations at the end of the course are recorded and used as part of the final examination. An example is given in Ref. 5.

4.2. Contract education for industry

The B.Sc. education at Uppsala University is closely connected to the industry already from the beginning. Within the program academic teachers and researchers collaborate with NPP staff and other experts from industry and authority to provide students with an unique learning experience. In some instances industry experts have participated in academic teacher training courses in order to better function in their role as guest teachers. The industry also provides students with access to their training facilities, e.g. full-scale simulators. All students that have graduated from the program have been offered positions at the NPPs.

Following a recent restructuring of Swedish nuclear industry training, much of the responsibility for the continued education of staff have been handed over from a dedicated organization to the individual NPPs. In a response to this change and following discussions with industry, the Nordic Academy for Nuclear Safety and Security (NANSS), a competence centre within Uppsala University has recently taken on the duty of developing and organizing continued higher education for NPP staff. The courses which are defined in close collaboration the NPPs will involve teachers and resources not only from UU, but also other universities, authorities and expert organisations, and will mostly be made available both on-campus and as distance learning [6].

4.3. Experience from E-learning

Most of the courses in the M.Sc. program in Nuclear Engineering at KTH are available as web seminars. Some courses have even tested electronic examination with the software Maple T.A. The main advantage is the shortened time for correcting exams, as well as infinite possibilities to change and modify questions.

During 2015 an E-learning strategy has been formulated and developed by/at KTH. This strategy is based on three pillars:

I. Promotion of the program and web-navigation through the entire TNEEM program.
   a. Short video presentation of entire program in a 4-5 minute video clip
   b. Each course is video presented and described by the course lecturer. Videos are recorded in a studio with slides and demonstration items.

II. Support and improve E-learning for registered students, mainly regarding the campus-based educational process, to enhance learning pace, better through-put of program students and higher average grades. Off-class activities, based on internet “Exerciser module” supporting processes of home assignments, problem solutions and electronic examinations, are developed through Maplesoft. Laboratory exercises will be modelled and simulated using E-learning platform through a special module of interactive laboratory simulations. Interactive laboratory simulations will be compulsory before conducting the laboratory exercises in “real space”. Moreover students will have a chance to re-simulate real exercises.

III. Distance education - education on demand for non-academic stakeholders, accessible only for our contractors, will be a tailored merger of Pillar I and II and specially developed distance education courses.

In autumn 2015 the E-learning approach was implemented in the Nuclear Reactor Physics Course at KTH. 38 students performed nine week assignments for 9 weeks. These students were examined for the first time ever at KTH in a fully electronic final examination based on the Maple TA platform through eight questions (and “sub-questions”). Each question was individualised so that the risk of cheating and copying of results was minimised. Once the students submitted the final answers they got immediately the final exam results. A very important pedagogical and educational progress has been achieved – a “zero time” delay between the exam and information about the results. The ambition is that by 2018 the entire Master program will be offered in the frame of E-learning technology.

4.4. Flipped class rooms

Chalmers has launched a project, Le@rn, with the goal of converting some key courses in their master program “Nuclear science and technology” to web based courses with flipped-classroom approach. Feedback from the students shows that the web-based flipped-classroom course format is much appreciated. Chalmers is using Learning Management Systems and Webcast recording and broadcasting in their courses. This results in a student-centred active learning and by flipping the classroom we can reach higher-order thinking skills triggered in the classroom, as compared to the traditional monolog structure of the lectures, see also Fig 3 on the old Taxonomy of pedagogical levels.

The flipped classroom allows active “in-class” learning activities. Two courses in applied physics were flipped: “Physics of nuclear reactors” and “Modelling of nuclear reactors“. The flipped classroom means that there are

(1) pre-class activities (out-of-class) for reading lecture notes, watching webcasts and answering quizzes. It is also possible to send questions and feedback to teachers.
(2) in-class activities for wrap-up sessions, brief chapter summary, peer discussion, tutorials and laboratory exercises
(3) post-class activities (out-of-class) include discussion fora, home assignments and preparation of lab reports.

The teaching using a flipped classroom resulted in a much more student-centred pedagogy, increased interactions between students and teachers, higher levels of thinking skills used, and most important: better results at the final exam.

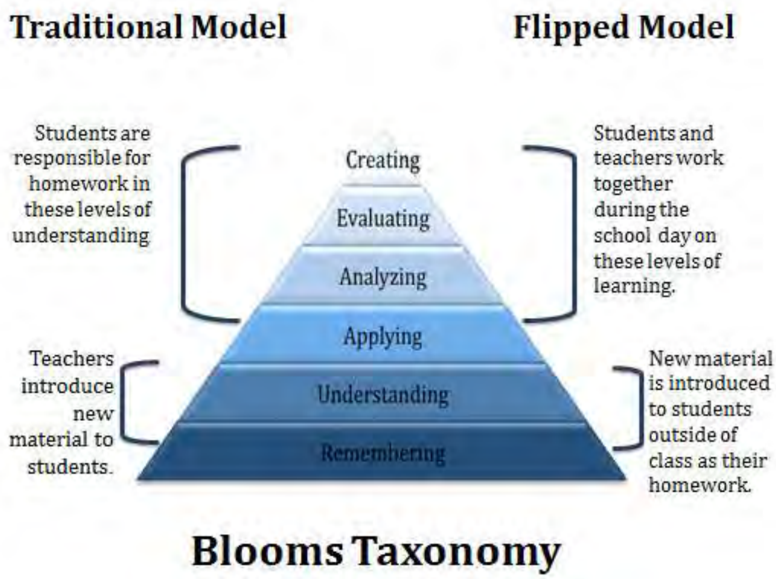

Fig 3. Pyramid of Pedagogical levels according to Blooms taxonomy, as seen from traditional teaching, and from a flipped model described in the text.

4.5. Workshop and poster presentations

There is within SKC an annual symposium for all to listen and present research projects related to nuclear technology. These two days are comprising both plenary and parallel sessions to cover overview talks, invited speakers, as well as students work.

A similar day for all Master students in Swedish nuclear programs will be held at Chalmers soon with the aim to give them a chance to present their work or thoughts to industrial representatives, as well as meeting with other students. This is also a way to let students promote their educational program, but also a way to meet industry.

5. Conclusions

There are many challenges ahead within nuclear, of which the most important is how to make sure that we can keep a strong competence in the field. The funding of nuclear education has been very fruitful, and should continue in the same manner.

There are however several tools to use and further develop to keep a strong nuclear competence in a small country such as Sweden, and to see a solution for LTO of the SKC:

- Industrial involvement in courses on all levels.
- Use of contract education for professionals mixed with students from undergraduate programs.
- Workshops for students so that they meet with other students, and are allowed to present their skills and ideas to industrial representatives.
- Further development and elaboration on E-learning, including electronic examination.
- New ways in teaching, such as the flipped classroom strategy.

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CROSS TRAINING AS BASIS FOR 3S SYNERGY IMPLEMENTATION

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ABSTRACT

In the nuclear industry, which includes a number of scientific and technical disciplines, knowledge is one of the most vital resources, which allows us to perform integrated approach to a facility operation. Compliance with safety & security requirement is a crucial part of daily plant maintenance. In the other words safe exploitation of nuclear energy requiring minimization of proliferation risks, probability of malicious acts, as well as prevention of nuclear accidents and mitigation its consequences. Safety, security and safeguards are three pillars defining by IAEA, and their synergy will increase the efficiency of plant safety and to identify and fill existing gaps.

However, by history these pillars are developed independently of each other and usually professionals have narrowly aimed knowledge and skills. Most probably an expert on nuclear safety could notidentify problems in security or safeguards, and vice versa. This situation is rather common and do not pose an any challenge for standard approach to nuclear facilities operation. However, in order to implement 3S synergy approach and increase a safety of nuclear energy, it is necessary to develop a cross training programs.

The paper highlights a main result on education programs analysis. Nuclear safety, security and safeguards courses offered in Russia were covered. The “Synergy professional competence map” and the roadmaps for cross training and professional education on basis of different S were developed. Achieved results is aimed on filling the existing gaps in Russian programs on nuclear education and it will be proposed to Rosatom Academy for further implementation.

Keywords: synergy, nuclear energy, cross training, knowledge

1. Introduction

With the development of nuclear energy the probability of malicious acts involving nuclear material and nuclear facilities are continuously increasing. Although nuclear industry maintains very high standards of safety, the possibility of an unintentional failure of the reactor and the release of radioactive substances into the environment is a significant risk. Also, the development of nuclear energy increases the risk of proliferation of nuclear materials. In this respect enhancement of security-related issues of nuclear facilities arose. The most important components of the safe operation of nuclear power facilities are safety, security and safeguards. That union is the basis of the concept 3S synergy, which provides a comprehensive approach to the implementation of the object of protection.

The most important part of the implementation of the principle of 3S synergy experts are equally competent in these three areas. To extend the knowledge held various training courses and seminars. These specialists will be able to identify gaps in other areas, as well as be able to use equipment that implements 3S principle. Thus, knowledge is one of the most important resources in the field of nuclear technologies and its security should conducted at the proper level for the safe operation of nuclear power plants. In order to bring together the necessary competence create competence map.

2. Competence map

Competence map is a set of competencies that illustrate knowledge and skills necessary to work effectively as part of a particular profession or position.[1]

As previously indicated, to get advantage from synergy of safety, security and safeguards are required qualified experts. The competence map to ensure proper training of employees was considered for this (Fig.1).

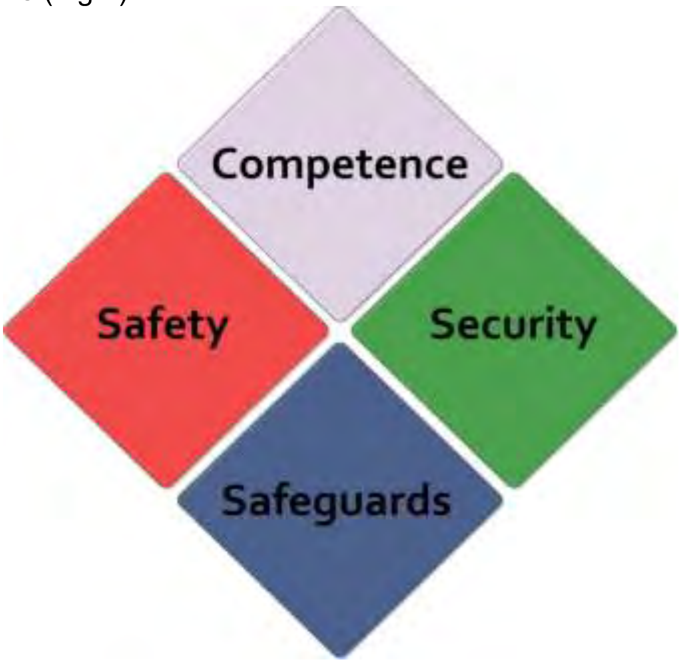

Fig 1. Competence map

Each area and its' specific skills are described below.

3. Safety

The main goal of safety is achievement of proper operating conditions, prevention of accidents or mitigate the consequences of accidents resulting in protection of workers, the public and the environment from sudden radioactive danger, according to IAEA definition.[2] Safety at the facility by means of appropriate equipment (passive safety elements, emergencyalarm system), appropriate technologies (probabilistic safety assessment, accident simulation) and the adoption of various documents at the international and national levels. Annually held a large number of training courses in the field of nuclear security workshops. Key issues include structural integrity and safe operation of nuclear power plants and research reactors, methods and equipment for safety assessment control. Figure 2 shows the competence of nuclear safety experts and relevant training courses.

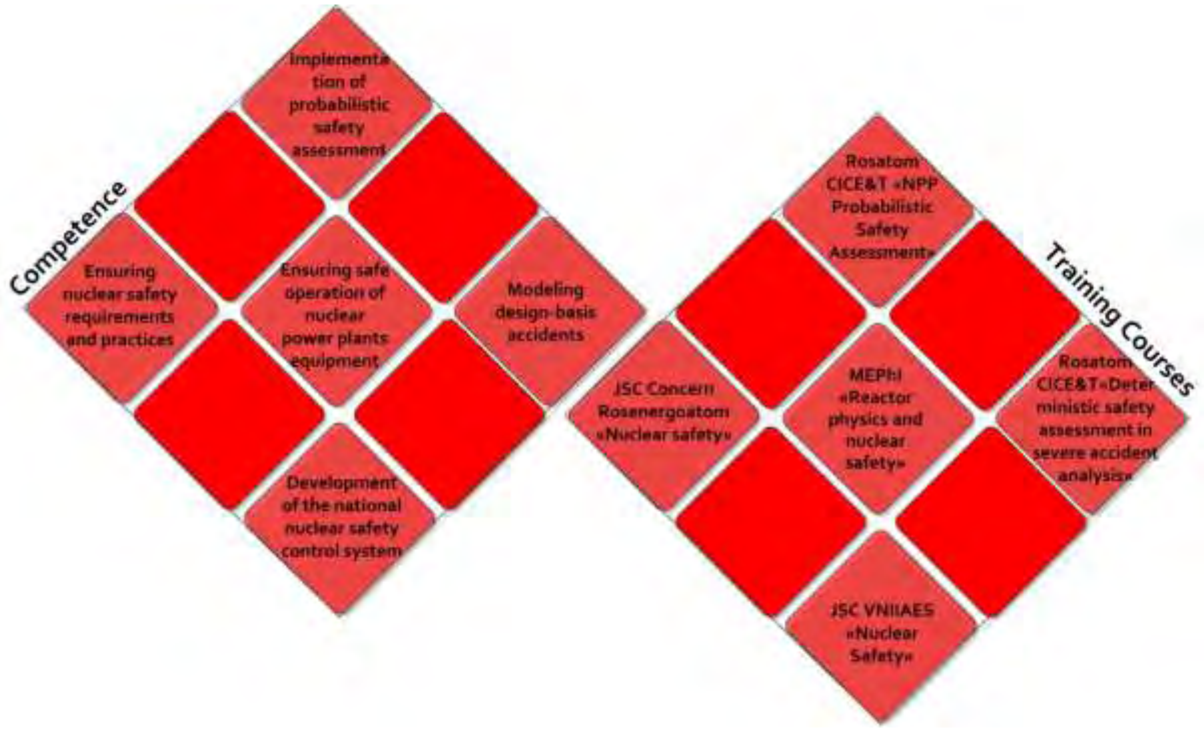

Fig 2. Safety competence

Consider the first directionin details. Probabilistic Safety Assessment - a comprehensive, structured approach to the definition of failure scenarios, which is a conceptual and mathematical tool for the numerical risk assessments. This competence involves the knowledge and skills of three safety levels of evaluation. Level 1 provides an assessment station failures, leading to the definition of core damage frequency. Level 2 includes evaluating containment reactions leading, along with the results of level 1, to determine the frequency of damage to the containment and release rate to the environment a certain percentage of the total number of reactor core radionuclides. Level 3 includes an assessment of the effects of off-site leadership, along with the results of assessment of the level 2, the risk assessment for the population.

4. Security

Securityis prevention, detection and response to theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear or other radioactive substances and their associated facilities in terms of the IAEA. In process of building a security system of nuclear facilities used differentiated approach, providing specific guidelines on threats to build a security system of borders.[3] The list of competencies for professionals in the field of securityis given in Figure 3.

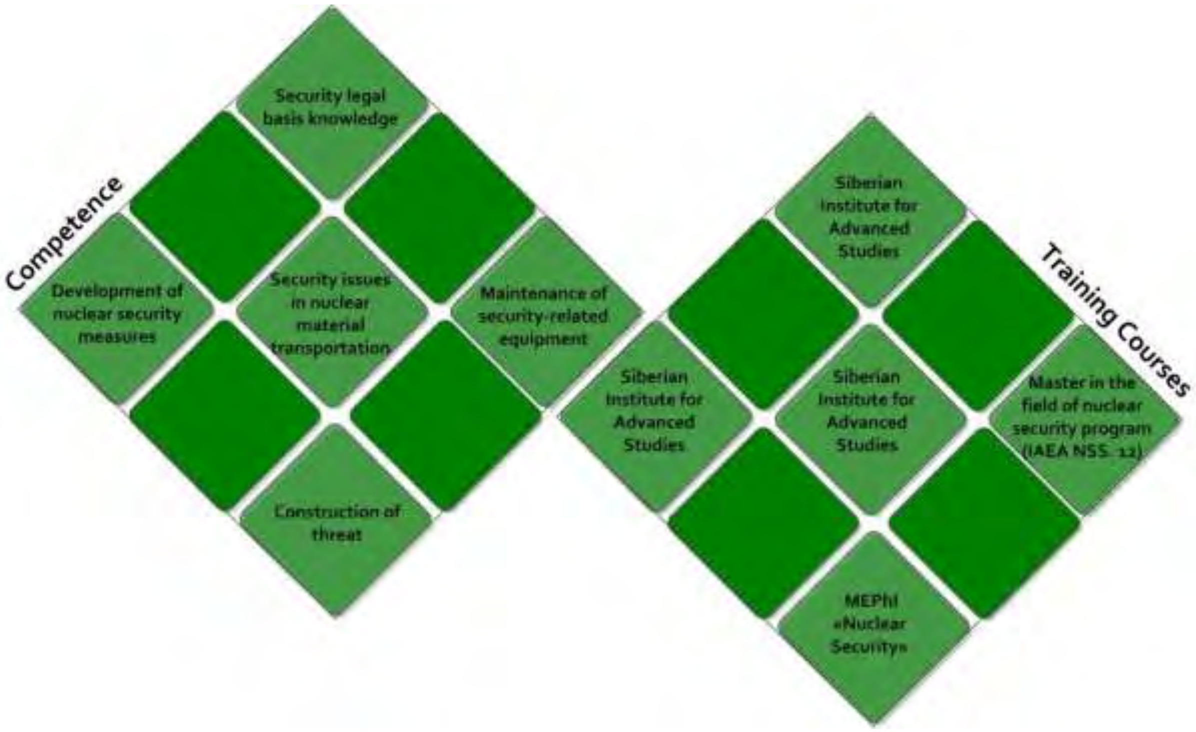

Fig 3. Security competence

These competencies can reduce the risk of unauthorized access to nuclear materials. Rather important aspect of security implementation is the building a threat competency 5). Competence provides a knowledge for development threat that allow to describe all possible intruders for the specific nuclear facility.This competence is based on an analysis of potential offenders, their actions and the subsequent formation of the security plan. Following this plan is a guarantee of successful prevention of the unauthorized action. The model is formed as a certain combination of characteristics, such as type of offender; intruder motivation; intruders' objectives on the analyzed object; possible quantity of a group, use of weapons and other technical devices; level of preparedness; object details awareness etc.

5. Safeguards

IAEA nuclear safeguardsis a tool used to verify compliance with state obligations obtained after an agreement with the IAEA non-proliferation safeguards on all nuclear materials, even in peaceful nuclear activities, and to ensure that such material is not diverted to nuclear weapons or other nuclear explosive devices. Competence of specialists in the area of safeguardsare presented in Figure 4.

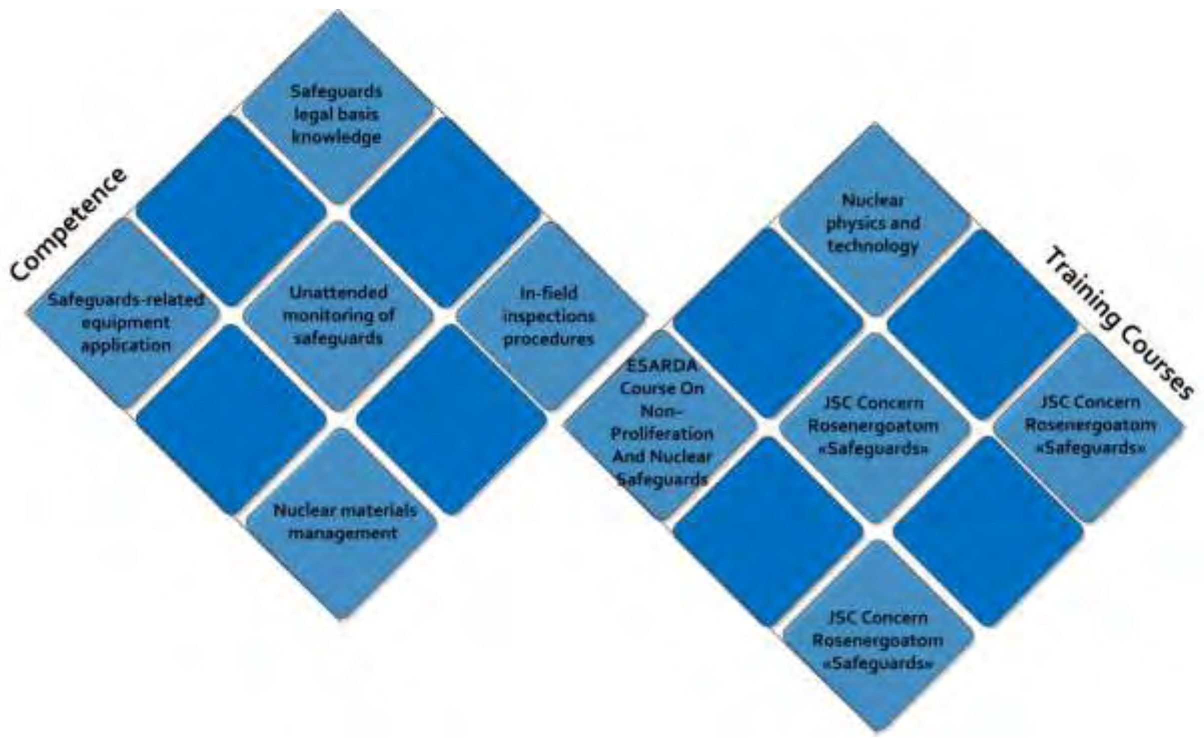

Fig 4. Safeguards competence

Technical equipment in the field of safeguards can be classified by control methods: non-destructive and destructive analysis. Non-destructive analysis methods include gamma spectrometry devices. Measurement equipment for destructive analysis used for the purposes of elemental analysis and determination of the isotopic composition of a probe.[4] There are also systems for data security, remote automated monitoring systems, sealing systems and optical-electronic surveillance. Competence 3 (Application of the technical aspects in providing safeguards) provides skills with technical equipment to ensure its safe operation and efficient application.

6. 3S Synergy

The combination of these three complementary systems (safety, security and safeguards) are the basis for term synergy. The process of realization of synergy is quite simple: if the action is one of the subsystems is reduced, then it will be compensate by means of another subsystem.[5]

Implementation of this principle requires unique professionals who are competent in the three areas at the same time.

There are a variety of training courses that provide knowledge in three directions - on nuclear safety, physical protection and safeguards.

One example is the course "Security and physical protection of NPPS and the relationship with safety and safeguards" Rosatom Central Institute for Continuous Education and Training (Rosatom CICE&T). The program is aimed at forming the next row of competences:

1. Knowledge of nuclear safety and radiation protection approaches.
2. Safeguards and accounting standards implementation on national and international level.
3. Implementation of threat assessment methods.
4. Physical protection systems design and evaluation.
5. Knowledge of physical protection technologies and equipment.
6. Knowledge of measurement methods in material control and accounting (MC&A) system.
7. Use of non-destructive and destructive analysis methods for MC&A.
8. Implementation of statistical analysis in MC&A.[6]

Thus, the experts can get on these courses skills in all three areas. However, not all the necessary competence to deal with in the course "Security and physical protection of NPPS and the relationship with safety and safeguards". After analyzing the gaps and overlap between competences and courses presented a roadmap.

7. Analysis of intersections and roadmap for training specialists

After consideration of all the areas of competence and synergy competence overall between synergy and above the security partition was found. During the comparison process it became obvious that not all competences included in the educational program of the course "Security and physical protection of NPPS and the relationship with safety and safeguards". Figure 5 shows the general scheme of competences. Competence that a highlighted red color, which are not addressed in the proposed synergy for courses in Rosatom CICE&T.

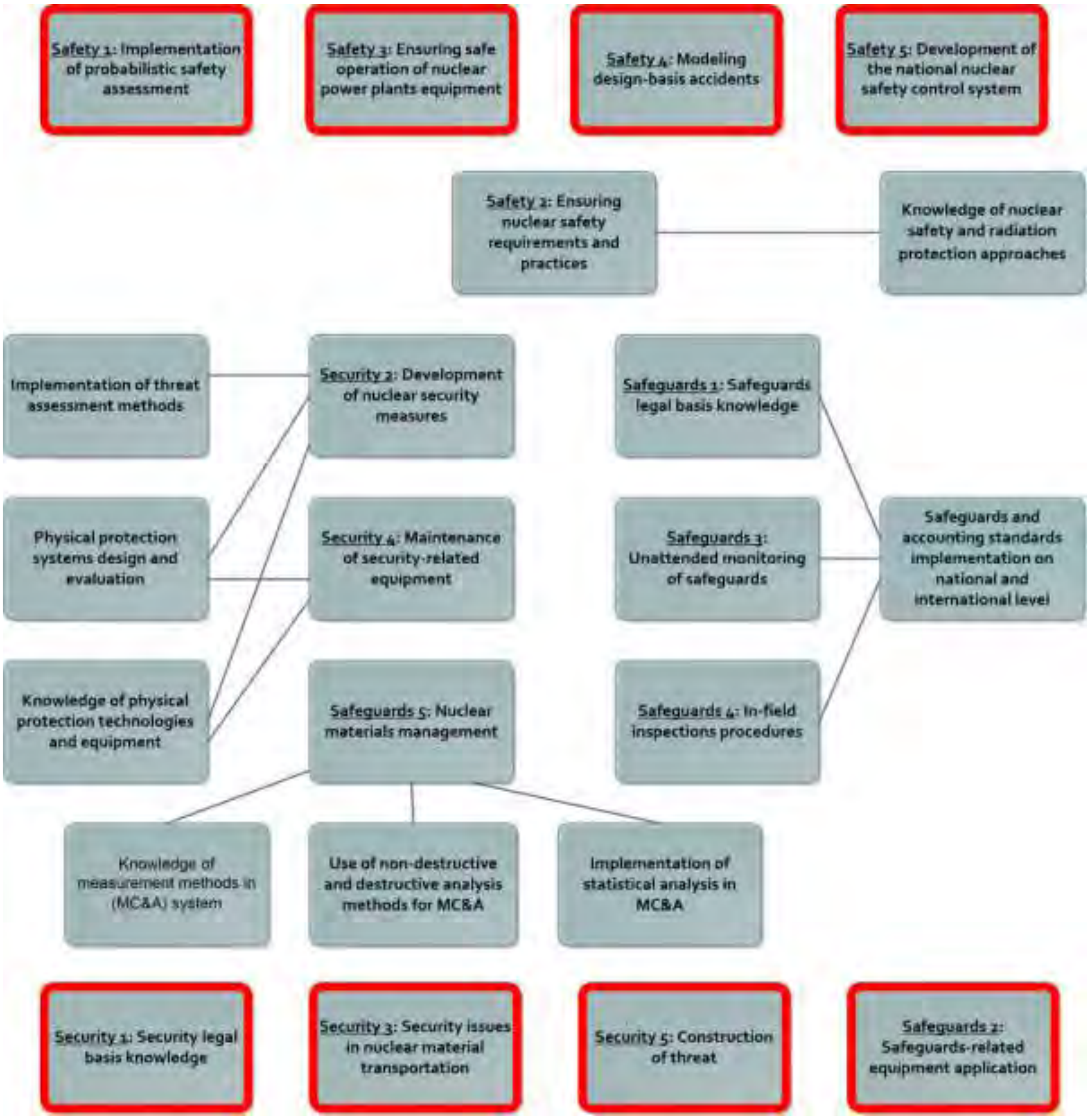

Fig 5. Competences chart

Thus it is seen that most of the data considered by the competence courses. However, in order to enable workers to ensure effective implementation of the concept 3S synergy, they must possess a full set of competencies included in the developed model. It is necessary to provide additional training of the students on course "Security and physical protection of NPPS and the relationship with safety and safeguards" to bring a set of competences they have received in compliance with the model. In order to comply this task, the road map (Figure 6), which offers training necessary for the development of competencies rates were developed.

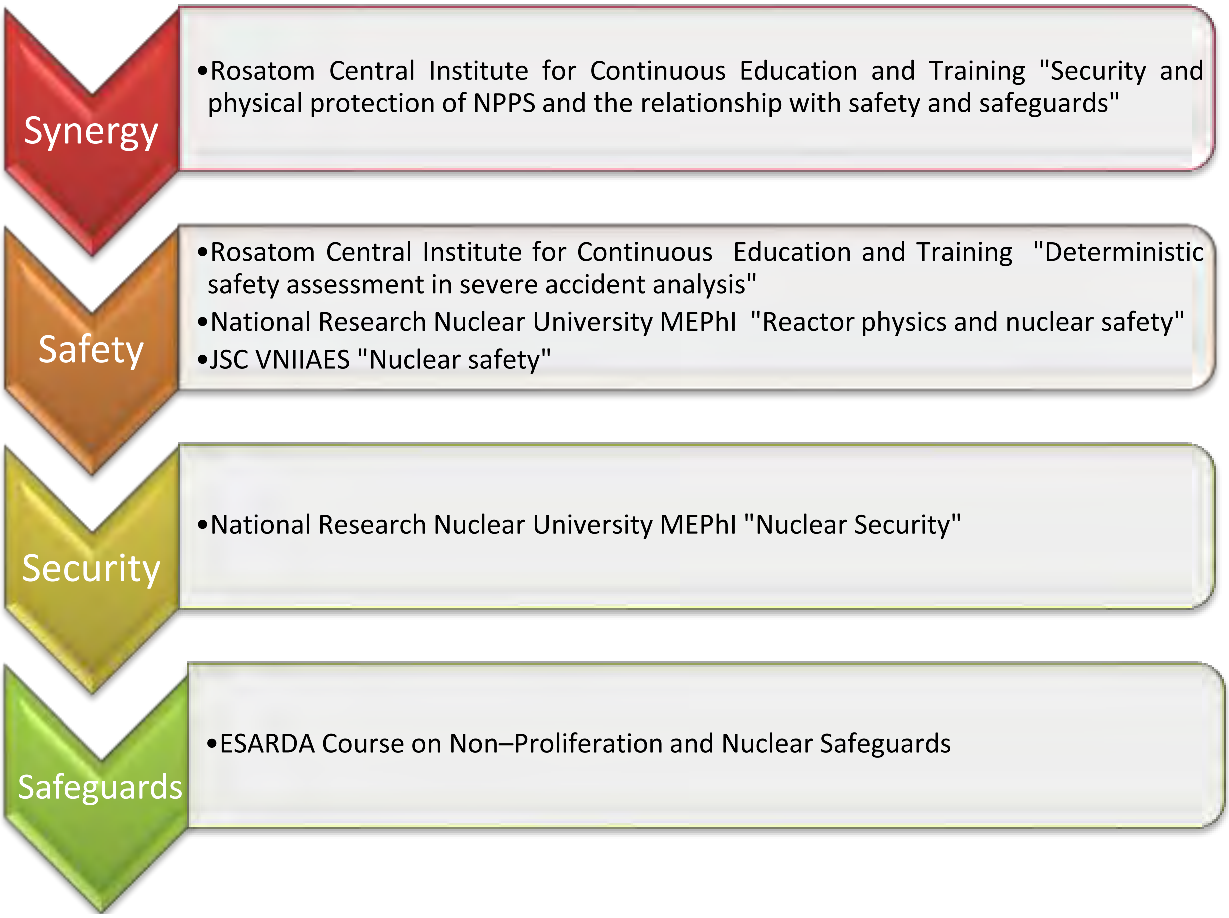

Fig 6. Roadmap of preparation of experts in the field of 3S

8. Conclusion

Implementation of 3S principle allows increase nuclear safety.[7] To implement this principle are needed an experts, that are competent in the related fields. Consideration of competences of these specialists is shown in a competence map. To train such specialists offered advanced courses, which will address topics on nuclear safety, security and safeguards. However, these courses can not offer a comprehensive set of competencies needed for synergy principle implementation. Therefore, we develop the 3S expert preparation roadmap that offers the possibility of acquiring the missing competencies. After analyzing the competence map, we can conclude that safety courses are rather narrow aimed and it would make sense to make a more general course that will cover all the areas of 3S. This will be an cost-efficient solution for training new specialists.

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A focus on excellence in project management: we are different! Are we different?

Specific Adaptations to Change and Configuration Control – Case Study based on a large EPC Project in the Nuclear Business

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ABSTRACT

A significant number of projects is affected by time or cost overrun during project execution. The reasons for these overruns can differ from project to project and all stakeholders may be involved. One of the many sources, which can cause the overruns, is the impact generated by changes required to be implemented into the project scope or generating rework.

Therefore it is of vital importance for projects to have a controlled way in which changes can be implemented. This is of special importance in the nuclear business, as further to the usual challenges of project management in view of meeting requirements related to quality, time and cost, the need for a complete traceability of change implementation through all design stages, manufacturing, installation and commissioning including all relevant documentation is mandatory.

Based on the example of a large, complex and long-term EPC (Engineering, Procurement and Construction) project with several thousand changes during project execution, change and configuration control needs arising during different phases of project execution are described. To address the upcoming needs tailored adaptations to the change and configuration control process had to be developed, focusing on maintaining a controlled environment as well as minimizing impact on time and cost. These solutions are briefly outlined and some recommendations given.

1 Introduction

A significant number of projects is affected by time or cost overrun during project execution due to different reasons [1]. One of this reasons can be the impact of change requests which all projects independent from the business area or country are subjected to during their execution. Change requests in principle can be triggered by all stakeholders. All of them must be handled by project management, assessed and resolved within the project organization with the objective to minimize the impact on scope and thus schedule and/or impact on cost.

Depending on the size of the project the amount of change requests can differ from a small number to several thousands. Therefore it might be a major task to handle them. The current examples for troubled projects from different industrial areas, like the Berlin airport or the Elbphilharmonie in Hamburg, indicate in an exemplary way the importance of a proper change control process. Generally, changes combined with problematic contracts may dramatically affect project execution and cause major delays, together with a significant impact to the project budget.

Due to the special demand from the regulatory bodies regarding traceability, verification and validation of changes it is even more challenging to handle modifications in projects within the nuclear industry. In order to be able to address these demands it is necessary to establish a systematic and rigorous level of project change and configuration control, together with a reliable way to trace the changes from design via installation until the finalization in the commissioning phase and to ensure implementation within all associated levels of documentation.

Based on the above described circumstances an example will be given how these special demands were addressed in a large EPC project, what challenges were encountered, how they were addressed and what kind of recommendations and good practices may be derived therefrom.

2 Key Figures

- Large upgrading project in nuclear power plant business
- Three party consortium
- Budget >> € 100 million
- Close to ten years project duration
- Several hundred people involved during project execution
- More than 250 suppliers and subcontractors involved
- Complex multidisciplinary interfaces with the existing plant systems as well as parallel ongoing modifications executed by customer and other contractors
- Unfavourable contractual environment hindering proper design freeze and allowing for continuous change and modification requests

The contracted scope consisted of work related to all technical disciplines, such as nuclear safety engineering, process and system design, piping and mechanical equipment, HVAC (Heating Ventilation and Air Conditioning), civil works, electrical switchgears, cable layout and cabling, earthing and lightning protection, emergency diesel generators, field instrumentation, instrumentation and control, simulator upgrade and control room design with a high focus on human factor engineering.

During the project execution several thousand change requests had to be handled. The huge amount of changes was driven by an ever increasing scope due to the project's complexity as well as a difficult and unfavourable contract.
Facing the above mentioned situation the project management had to define and continuously refine a suitable process to treat the changes, making sure that the implementation on site was executed in an effectively controlled manner and that the verification and validation was mastered to comply with regulatory and customer requirements.
The outcome was strict change and configuration control supported by a software based issue tracking tool usually used in the development of software solutions.

3 Change Management and Control

In order to ensure a fast treatment of the change requests the project management decided early to set up a change control board with participants from all technical disciplines. The meetings were led by the change manager together with the sub project managers for the main technical areas. During the board meetings all new upcoming technical changes were assessed, the needed tasks identified and finalization dates agreed.

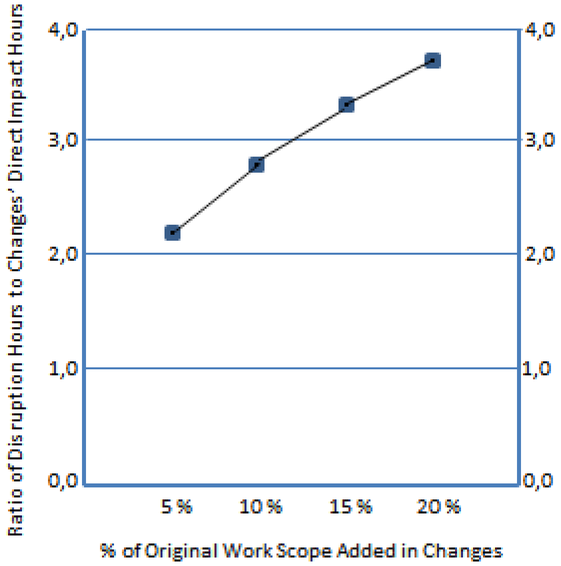

Fig 1: The Growing Cost of Disruption Relative to Amount of Change [3]

As an outcome of these assessments a tool supported process was launched where all tasks were assigned to the responsible engineers. By using a tool supported process the project management was able to check the progress regarding the issue resolution together with the status and the engineer responsible for solving the issue at any time.

All information was aggregated in management overviews based on web-based dashboards accessible from every computer, always reflecting the current status. The gathered information related to status, revision and progress as well as implementation status was used as the basis for the verification and validation of the changes.
During project implementation on site, the project management was forced to adapt and reinforce the change control process due to the amount of change requests still arising at this late stage of the project.

In general, the impact of many changes is greater than the sum of the impact of the individual changes [2]. That means that by adding new changes the impact increases significantly until a point where the normal project execution is completely disrupted and the expected progress

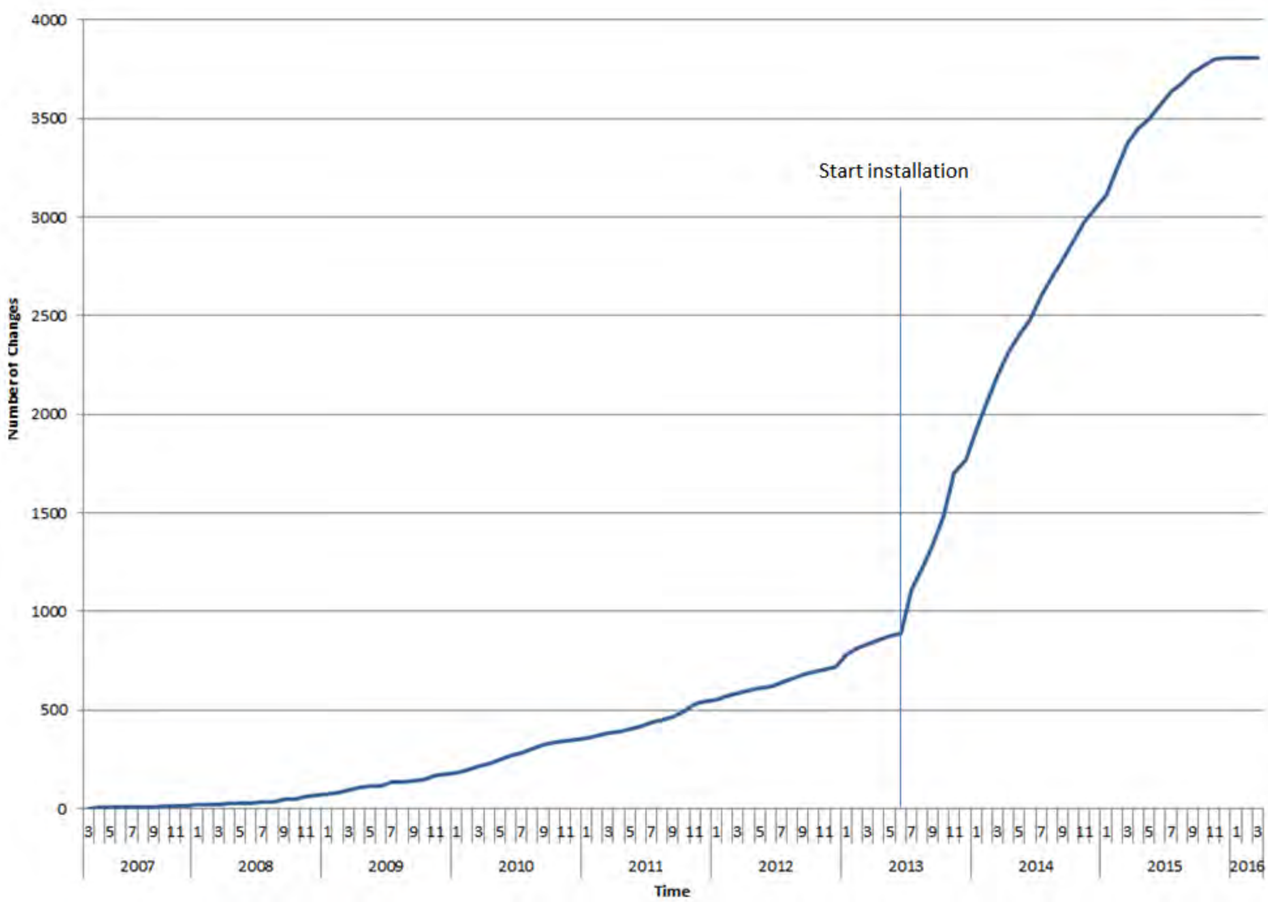

Fig 2: Amount of changes during project execution

cannot be achieved. This effect is even greater when complementary changes occur during the installation and commissioning phase, disrupting the physical work on site. Figure 2 illustrates the development of the change request situation within the project after start of physical works on site.

4 Approach to minimize the impact

The decision was taken to cluster the change requests upcoming during installation and commissioning according to their severity. In general a distinction was made between:

- Adaptations (changes in documents and drawings in case of obvious errors or mistakes with no significant influence to the installation and commissioning work – 40% of the project change requests)

- Modifications (alteration of a system, component or structure of approved detail design in such a way that it is no longer meeting the requirements of the design bases - 60% of the project change requests)

Based on project experience, changes (modifications, for adaptations this is not the case) which will be implemented in a later phase have a more severe impact than change implemented in an earlier stage. Schematically the increase can be described as shown in Figure 3.

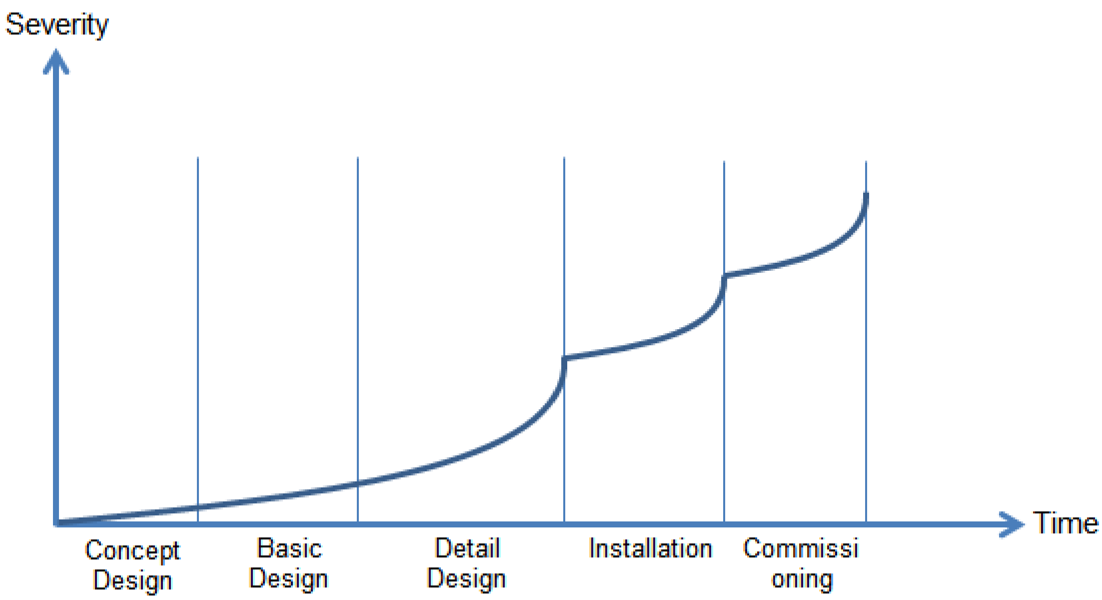

Fig 3: Severity impact

The steepest increase in severity is at the end of one phase before starting the next one with the finalization of the baseline. Especially before installation start it is critical to finalize all design issues. Without a design freeze and a completely finalized installation documentation the impact of introduced changes is most severe. These facts determined the approach of dealing with the change requests remarkably.

For the project execution, implementation dates were decided based on the category of the change requests. Whenever possible, adaptations were directly implemented as a “quick fix” in order to disturb the ongoing installation and commissioning activities as little as possible. For modifications a lot of preparatory design work was necessary, before the implementation work could start. In addition often changes would interrelate to each other and had the capability to mess up the work. Therefore these changes were implemented as package consisting of a controlled scope with a detailed analysis regarding the impact to ongoing or already finalized installation and commissioning work.

The amount of modification packages required the definition of complementary intermediate configuration baselines and an allocation of the modification packages to these baselines to make sure that important functional project milestones, such as different installation and commissioning steps could be met.

A further step of reinforcement in the change and configuration control process became necessary during execution of the described approach due to the fact, that the amount of changes combined in large packages threatened the correct performance of installation and commissioning activities.

The release process of the change request packages was adapted to a two-step approach. The first release step allowed the engineering and purchasing teams to perform relevant design works and procurement activities. This means the necessary documentation and material for the work packages was prepared and organized in the back office and the on site design office.

When a reasonable packaging of change requests was reached, the scope of work connected to this intermediate baseline was frozen. With the second release step the finalized design for the change request packages were handed over to installation and commissioning for implementation and verification. Figure 4 illustrates how the changes were implemented in consecutive waves, with the respective teams only starting when the previous package had been completed.

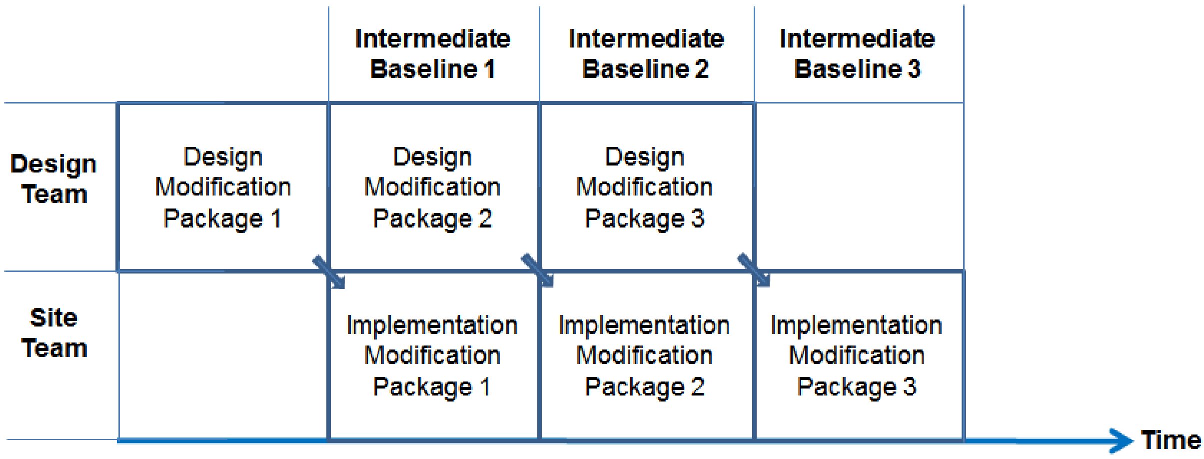

Fig 4: Concept of implementation

This approach gave the project the necessary flexibility for implementation of changes, but at the same time enough time of undisturbed work for the installation and commissioning team to successfully finalize certain work packages and hand them over to commissioning for testing and verification.

5 Lessons Learned and Recommendations

Nonetheless even the most flexible or sophisticate approach can only mitigate the impact of changes related to time and cost. As a lessons learned out of the project some principles and best practices became evident.

Most critical for the project success from a change management point of view is the preparation of the change control strategy linked with the configuration control directly from the start of the project, supported by a software solution capable of issue tracking and baseline control. It is of vital importance to enforce the strict application of respective processes, procedure and tools on all parties of the project.

In every project certain baselines are evident from the beginning. The projects normally have certain design phases (e.g. concept design, basic design, detail design), a manufacturing step as well as an installation and commissioning phase.
It is obvious that it makes sense to define the baselines accordingly. These baselines are then, together with the time schedule the tools for allocating and implementation of upcoming changes. Together with the configuration management it is important to finalize and verify the changes allocated to one baseline, before starting the works related to the next one. This is most important for the step from design to installation, as consequences prove to be most severe otherwise.

Following this approach during project execution enables the project team to handle all changes in a controlled and structured way. It also creates less disturbances within the organization and therefore mitigates the impact of changes to the schedule and project budget.

However, in case of a troubled project, this basic approach is not always sufficient. As described in chapter 4 it could be necessary to adapt the process.
Two approaches have been observed:

- Either the complete stop of change implementation on site, meaning the installation (and commissioning) of one configuration is fully completed before handling any further change

- The other – as described above – a continuous and controlled package wise implementation according to intermediate baselines satisfying project milestones on the way to completion

A full stop of change implementation on site for a lengthy period of time usually results in an increased impact on time and cost, when the point of time is reached, where the changes from technical perspective must be implemented. Extensive rework on site may occur, including dismantling of already installed equipment and refurbishing with modified components leading to remarkable time and cost overruns.

It is our recommendation from observation and comparison with other large EPC projects, to have a certain way in which changes can be implemented into the design, installation and commissioning works.
Project management should not be reluctant to reinforce change and configuration control e.g. by adapting the way of handling change requests, introducing additional baselines, and even change the complete process, if necessary, to successfully manage the conflicting targets of minimizing cost, ensuring project progress as well as a controlled configuration.

6 Conclusion

Change management and control is one of the most underestimated tasks, especially at the beginning of a new project [4]. In order to mitigate the impact of changes, change management and configuration control should be part of the project organization and processes from the beginning. Together with defined baselines and the alignment of the baselines with the time schedule a good basis for successful change management is given.

This is especially necessary in projects in the nuclear industry. In order to fulfil the demands from regulatory authorities it must be always possible to track changes through all affected disciplines. Based on that it is possible to demonstrate to customer and regulatory authorities, that all changes are implemented, verified and validated, which is a requirement before restart of the plant.

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EXCELLENCE IN PROJECT MANAGEMENT – WE ARE DIFFERENT. ARE WE DIFFERENT?

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ABSTRACT

The nuclear power industry is capital intensive where costs are hard to predict and quality requirements, regulations and complexity of technology are demanding. The industry is global and therefore confronted with great diversity of every imaginable hard or soft factor. It is a great challenge for project management. However, all research and statistics indicate that the root causes of poor project executions, cost and schedule overruns of any industry are most often both more structural and more controllable. What lessons can be learned from successes and issues in large and complex projects outside the energy industry? There are four prominent topics. First, it is about a system's view, as project managers need the capability to deal with the project as a whole and in the context of a wider system, rather than in isolation from its environment. Second, it is the growing demand in leadership, as it is a key variable in the success of a project, and greatly impacts the project philosophy, culture, and the ability of the project to develop an emergent strategy and to deliver a successful outcome. Research reveals that this most important skill is among the weakest competencies for today's individual managers. Third, it is a closer look on buffers and reserves, that is reflected in the critical chain project management and based on the "theory of constraints". This approach keeps work in progress to a minimum level, speeds up the process and improves performance. Finally, it is the challenge of change management which is an ultimate discipline for global complex projects that are dynamic, diverse and emerging systems. Such complex projects require to constantly adapt their strategy and implementation plan with the focus on the strategy and continuous knowledge, stakeholder and political management as the key vehicle to get there. These changes are far-reaching and most responses are challenging.

1. Introduction

The nuclear power industry is capital intensive where costs are hard to predict and quality requirements, regulations and complexity of technology are demanding. The industry is global and therefore confronted with great diversity of every imaginable hard or soft factor. It is a great challenge for project management. Therefore, this industry could be the benchmark – but maybe isn't. The wisdom of benchmarking is learning from the best – beyond your own industry.

In fact, all research and statistics indicate that the root causes of poor project executions, cost and schedule overruns of any industry are most often not regulatory-driven changes and delays or force majeure but rather more structural and more controllable.

There is a lot going on in the project management industry, both in the classical as well as in agile approaches. What lessons can be learned from successes and issues in large and complex projects outside the energy industry? There are four prominent topics. These include: a system's view; a growing demand in leadership; a closer look on buffers or reserves and finally the challenge of the management of change. I would like to highlight them within a broader and high level picture.

2. Systems Thinking

Systems thinking is a conceptual framework that is of high value to effectively deal with the increasing complexity and rate of change in our world. System thinking is not a new perspective. It originated in 1956, when Professor Jay Forrester founded the Systems Dynamic Group at MIT's Sloan School of Management. Still, it is not necessarily common in all standards.

A lot matters on how you define the boundaries of your relevant system. In the "good" old days, project management was thought of as occurring within the limitations of a "controlled environment". Project managers need the capability to deal with the project as a whole and in the context of a wider system, rather than in isolation from its environment. This wider system includes networks, alliances and partnerships. Depending on the subject and perspective the system is not monocentric but rather multi-centric regarding power, decisions, interests or engagements. Projects operate within larger systems which are socio-technical systems encompassing interdependent technical and social elements. The systems thinking approach contrasts with traditional analysis, which studies systems by breaking them down into their separate elements.

Feedback is an essential component of systems thinking. People tend to think linearly, while in practice most connections are circular often reinforcing each other in a dynamic way. We often have multiple causes of an effect and multiple effects from a cause. Making for example a Causal Loop Diagram brings circular reasoning into focus. Any change of one element, let it be a social or a technological one, initiates reactions and even pro-actions of others. The intensity increases with the diversity to be managed and the digitalization of the work environment, as well as that of social life, and the capability of the elements to communicate with each other. Opponents typically are more motivated and willing to communicate than promotors.

Stakeholder identification, analysis and the management of their expectations, therefore, has become a much more challenging task than ever before. In many projects, it is the failure to deal with these forces which drives project failure. Internationally, project performance measures are moving away from simple inputs or outputs to be based on project outcomes and impacts. Outcomes and impacts are what ultimately matter to people. The consequence is that stakeholders and human connections matter more than ever and this is growingly reflected in any project management standard.

3. Leadership

In the past decades most attention has been given to develop project management and management in complex and multi-cultural environments. A study of IATA's cross-cultural leadership program suggests that the following steps can help organizations in multi-cultural work and business environments to tackle the important but difficult task to develop individual leadership competencies and build bridges across different cultures.

- Identify two cultures that need to collaborate and determine potential gaps between the "home" and "target" cultures.
- Identify leaders and leadership talent from each culture. Make a thorough judgment on which leaders are sufficiently culturally intelligent to develop for cross-cultural integration and collaboration.
- Identify appropriate pairs of co-leaders. Look for a past track record in multicultural environments, a willingness to become team-players, high growth potential and an open-minded, empathetic nature.

- Identify real projects. Use real business projects which enhance the learning experience during an intercultural program.
- Identify a realistic time frame. A minimum of three to six months is a reasonable time-frame for start-up activities, content delivery and evaluation. Often more time is needed.
- Share practices. Share both “good” and “bad” practices, working closely together and adopting an enquiring rather than judgmental mindset.
- Adapt for the next cross-cultural challenge. Adapt the lessons learned. Cultural programs should not be replicated in their entirety because markets and cultures differ.

In fact, this approach is good but it deals more with a quite simple phenomenon, the transition or transfer to another country’s cultural environment. The real challenge is diversity. The more global the business the more we have to manage diversity – or better we need to lead diverse teams, environments and stakeholders. It is much more than to build bridges in managing people putting the notion “management” first. It is great time to (re-)discover that the soft factors are the really hard ones. Leadership is a key variable in the success of a project and greatly impacts the project philosophy, culture and the ability of the project to develop an emergent strategy and to deliver a successful outcome. While management is more about being most efficient in existing paradigms and business models, leading is more about giving and being responsive to new direction, changing the paradigm and developing or testing new business models. Central to the practice of good leadership is the capacity of the leader to engage stakeholders both internal and external, to inspire and empower people and to develop strong interpersonal relationships with the highly diverse team members, clients and senior management.

A study by the Center for Creative Leadership (CCL®) found that the four most important skills or capabilities needed by organizations in the future - leading people, strategic planning, inspiring commitment, and managing change - are among the weakest competencies for today’s individual leaders.

Leading is about supporting people to become successful and, therefore, success results from leadership. Different leadership cultures serve different purposes. There are various reasons for this. Our environment is becoming more uncertain and less predictable. The rates of change and innovation increase and require faster decisions in shorter time intervals. Automation and digitalization are entering the knowledge industry. IT projects are often the frontrunners for new approaches in leading and managing projects.

The changes are dramatic and speed up the revival of McGregor’s Theory Y of the sixties. McGregor's ideas suggest that there are two fundamental approaches to managing people, Theory X and Theory Y. Many managers (still) tend towards theory X, an authoritarian perspective, assuming that people are unwilling, incapable and have a strong need to be micromanaged. These managers generally get poor results. Such leadership is often referred today as being one of the level 1.0. Enlightened managers use theory Y, a primarily empowering perspective, which produces better performance and results and allows people to grow and develop. They believe in people being willing and interested to perform quality work and assume responsibility.

Approaches focusing on flexibility, collaboration, crossing boundaries, collective knowledge and collective leadership are increasingly more in demand than simply meeting Key Performance Indicators. It becomes more important to seek a balance between developing leaders through individual competencies and fostering the collective capabilities of teams, groups, networks, and organizational leadership. This assumption is, too, one of the foundations of the agile manifesto. As a consequence, successful managers drive

- Away from Taylorism, which alienates workers by treating them as mindless and easily replaceable factors of production, towards process and network thinking
- Away from the individual and lonely heroes and specialists towards collaboration and interdisciplinary teams
- Away from traditional business models toward new business models of co-creation, co-production, et.al. or even disruptive business models
- Away from homogenous teams, i.e. “same breed”, towards diversity and heterogeneous teams and managing those to initiate innovative problem solutions
- Away from isolated islands of knowledge towards collective knowledge
- Away from hierarchical micromanagement towards self actualization, self organization and empowerment.
- Away from fixed and rigid working times toward more geographical and time flexible new models.

These changes reflect the new dynamic in the agile-driven discussion of situational leadership that has come up. Choosing the right leadership culture is the difference between success and failure.

The bad news: The picture that you get in the daily business of organizations is that the next generation of managers get trainings in new approaches on how to manage and lead people, level 3.0, only to realize at their return that their superiors still behave as managers of the 1.0 level – and that they have to align again.

4. Critical Chain Project Management

Another best practice, Critical Chain Project Management, is highly effective in dealing with uncertainty and limited resources, especially in complex and multi-project environments. Planning for an upcoming projects requires estimates for the activity durations. Uncertainties are evaluated and contingencies planned. Much time is spent on this in order to get a highly reliable and confident schedule. A typical risk averse attitude will prevail putting sufficient safety buffers for each activity that sum up to a gigantic project buffer. Resources working on activities usually hesitate reporting any early finish. If it is reported, the next project will probably be based on a risky optimistic figure. Critical Chain Management deals with this issue by extracting the buffers and applying a project buffer instead.

“Little’s law” and The Theory of Constraints (Goldratt) are core elements of this concept which keeps work in progress to a minimum level, speeds up the process and improves performance.

The core element **“Little’s Law”** is a foundation of queue theory and defines the relationship between Work in Progress (WIP), Throughput and Lead Time.

Two practical life examples: planning WIP above 100% in practice initiates a helix of negative effects, e.g. negative multitasking. Multitasking kills the flow. Studies say 15-30 min are necessary to become performant again. In contrast, giving too much time extends the cycle time and leads to what is called the Student Syndrome and also contains elements of the Parkinson Law. The student always eats up his buffers at the beginning before even starting his job. Parkinson law refers to the effect that people always need the time available or given to fulfill the job.

The **„Theory of Constraints*“ (TOC)** suggests to undergo five step iterations to continuously improve the constraints of a system, while trying to balance the system – at least temporarily:

1. Identify the system's constraints
2. Exploit the system's constraints using the method of Drum-Buffer-Rope
3. Subordinate and synchronize everything else to the above decision
4. Elevate the performance system's constraints (break the constraint)
5. If in the previous steps a constraint has been broken (Go Back to Step 1)

In this concept, the Drum-Buffer-Rope is a method that helps to focus on the element with the system's critical constraint.

- **Drum** is the synonym for the speed at which the constraint runs, sets the "beat" for the process and determines total throughput.
- **Buffer** is the synonym for the level of inventory needed to maintain consistent production
- **Rope** is the synonym for the signal generated by the constraint indicating that some amount of inventory has been consumed and refers to the well-known Kanban.

The benefits of the critical chain approach are that the optimization of constraints improves the production capacity, reduces the lead times with a much smoother and faster product flow and finally reduces the WIP and inventory.

Critical chain is gaining attention, but to be successful it requires a specific organizational philosophy and behavior that induces a severe change for most organizations. The whole system must fit. In this approach, as in many others, it is not the software that will make it work but how disciplined management and operations execute their responsibilities. It requires the buy-in and endorsement from management and executives.

5. Management of Change

Finally, market transparency, labor mobility, global capital flows, and instantaneous communications have boosted the speed of occurrence and gravity of impacts of risky events.

Change Management and Change Leadership in Balance

Change Management is much about controlling change and reducing impacts of changes. It includes processes of review and authorization for evaluating potential adjustments to facility design, operations, organization, or activities prior to implementation. This is done to make certain that no unforeseen new hazards are introduced and that the risk of existing hazards to employees, the public, or the environment is not unknowingly increased. In this context, it is for example a gigantic task to generate, retain and retrieve accurate and traceable information for updating and inspecting throughout the lifecycle of a power plant or any other major energy project. It is a fundamental task that certainly goes beyond the requirements of any other industry.

Ongoing change management of technology, requirements or attitudes and behaviors is a constant challenge in a complex multi-cultural and diverse management environment, but change leadership is a key discipline for global complex projects that are dynamic, diverse and emerging systems.

Change leadership is about driving forces, visions and processes that fuel large-scale transformation. The nuclear energy sector lives with such complex projects that require it to constantly adapt the strategy and implementation plan with focus on the vision and continuous knowledge, stakeholder and political management as the key vehicles to get there. This includes the alignment of stakeholders, the creation and development of the project culture, the creation, development and adaptation of the latest technology as well as the application of latest risk based performance standards.

Out of the many reflections, one could derive to guide change leadership there is one concept that is worth mentioning. It is a risk management perspective that still allows empowerment, self-management and a holistic perspective. This concept is called VUCA, founded by the US Army War College and helps to navigate in a world of growing confusion through evolutionary purposes and “unknown unknowns”. It is very closely linked to an agile response of management. Black swan events, such as sudden policy shift on nuclear power, technological advances or digital trends that come as a surprise are an increased occurrence in our world and become our “new normal”. Digital forces are disrupting traditional and enabling new businesses. E-mobility, real-time metering or smart grids have the power to turn power consumption data into the gateway to customer behavior. As a consequence disruptive business models are emerging.

VUCA stands for volatility, uncertainty, complexity and ambiguity of general conditions and situations of the business context along the two dimensions of how well people can predict the outcome of their actions and how much they know about the situation.

- V = Volatility describes the nature, dynamics and speed of change. The problem is unexpected and may be of unknown duration, but knowledge is usually available and the solution maybe expensive. There is a risk but you can cope with it by being prepared and having buffers.
- U = Uncertainty describes the lack of predictability and the prospects for surprise, but the basic cause and effect are known and a change is possible. There is a risk but you can cope with it thanks to more and better quality information.
- C = Complexity describes the confusion resulting from multiple interdependencies of forces and impacts. Some information is available but the volume can be overwhelming to process. Cope with the risk by decomposing and developing adequate expertise to address complexity.

- A = Ambiguity describes the surprise of reality, for misreads and mixed interpretations. Causal relationships are absolutely unclear. You face the unknown unknowns. Face the problem with an experimental and open mindset for new hypotheses and testing.

The particular meaning and relevance of VUCA relates to how people view the conditions under which they make decisions, plan, manage risks, foster change and solve problems. It discusses systemic and behavioral failures which are a characteristic of organizational failures. It recognizes that it is not enough to train leaders in core competencies but also to ensure the mindset is established for strategic and operational leadership in tense and critical situations.

6. Conclusion

There is a lot going on in the project management industry. There is a leitmotif for many practices that are changing. They all are systemic and foster agile approaches. All these changes are far-reaching and most responses are challenging to conservative management environments. We see new multicultural patterns emerging with very diverse forms and options of collaboration arising and increasingly finding followers. I believe this is reason enough for the nuclear energy industry to have a closer look on these evolutions or partly revolutions.

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Combining theoretical and practical courses for the comprehensive competence building

TRANSLATING THE EXPERIENCE FROM FULL-SCALE PLUGS AND SEALS EXPERIMENTS IN TO A COMPREHENSIVE DOPAS TRAINING WORKSHOP

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ABSTRACT

The DOPAS project is a four-year demonstration project in geological disposal funded with the partial support of the Euratom 7th Framework Programme. The DOPAS project consortium of 14 organisations from eight European countries has carried out partly or fully five experiments in France, Czech Republic, Sweden, Finland and Germany. Inside the DOPAS project, a five-day training workshop was carried out in September 2015 in the Czech Republic. The training planning was based on four major learning units and related learning outcomes including the provision of a full learning cycle with both theoretical and hands-on application of the tasks needed to plan, to construct, and to monitor a full-scale in-situ experiment. The trainers were mainly the experiment and work package leaders of the project from eight partner organisations. The curriculum followed the content of the DOPAS project plan starting from requirements and finishing with the technical feasibility considerations related to plugs and seals giving the participants an opportunity to construct and reflect on their own country's approach in contrast to the DOPAS approaches.

The training workshop was run with great success and very favourable replies were received from the participants and from the tutors to the extensive feedback collected.

1. Introduction to the context of the training workshop

The DOPAS project is a Euratom 7th framework project that focuses on full-scale demonstration experiments on the plugs and seals needed for the geological disposal facilities to operate and perform safely at different time scales and in different host rock environments. A 5-Day Training Workshop on the Role of Full-scale Experiments on Plugs and Seals in Demonstrating Safety and Performance of Geological Disposal was included as a part of the knowledge transfer and experience dissemination activities of the project for technical and scientific audiences, mainly young scientists, professionals and postgraduates in geological disposal.

This planned DOPAS dissemination activity had the objective to add to the scientific integration of the results and lessons learned and to share these by training of students and engineers from the EU Member States. Further, the training was targeted for participants outside the project consortium and it was intended to capture all the stages of the DOPAS work plan. An additional objective was also to define the training so that at a later stage the recognition of the learning outcomes from the training workshop could take place e.g. according to using the ECVET tools (5).

The training was designed and implemented in September 2015 after the project had been running around three years. This enabled a training design that was based on the project's original conceptual framework and at the same time, it exploited the lessons learned during the three years of implementing the experiments. The project and the training workshop started from the requirements, safety functions, and constraints of plugs and seals leading into the implementation of full-scale construction of monitored repository plugs and the development shaft sealing components. The training workshop was designed to provide the participants a full learning/action cycle[1] including both theoretical knowledge and practical skills acquired in team work and in an underground training facility environment, the Josef Underground Laboratory in Czech Republic, at the Czech Technical University in Prague and at UJV Rez, a. s. The trainers for the workshop came from eight project partner organizations sharing the experience from all of the five DOPAS experiments: FSS in France, EPSP in Czech Republic, DOMPLU in Sweden, POPLU in Finland and ELSA preparatory experiments from Germany.

The training process included the planning, implementation and assessment of the workshop that is reported as a part of the DOPAS project including the training materials that will be publicly available on the DOPAS website http://www.posiva.fi/en/dopas at the end of the project. The following chapters describe the content of these stages.

2. Planning for the DOPAS training workshop

The initial ideas for the DOPAS training workshop were produced in collaboration with Posiva Oy and the Czech Technical University's (CTU) Centre of Experimental Geotechnics in June 2013, when the location and the time for the training was agreed. The week in September scheduled for the training provided unhindered access for the trainees to the Josef Underground Laboratory and research centre. The other training locations were at the faculty of Civil Engineering at the CTU in Prague and at the UJV Rez, a. s. in the Czech Republic.

The detailed content planning for the training started in May 2015 together with the eight consortium members complemented. Four planning meetings were held using remote connections (teleconferencing and a video link) and two weeks prior the meeting a face-to-face material review meeting was held in Helsinki, Finland. The planning consortium consisted of Posiva, SKB, Andra, CTU, SURAO, RWM and GRS complemented with UJV Rez staff and with training materials from Nagra adding the ninth member to the planning group. The duration of the training workshop was fixed to five days. In addition to the planning group members, the practical implementation of the training workshop was carried out with the help of additional tutors and lecturers from the Czech Republic.

[1]see Kolb, Lewin, and Dewey (1984) later in the text

Planning group member	Organisation, country
Marjatta Palmu, task leader of the training workshop, WP6 leader of DOPAS	Posiva Oy, Finland
Radek Vašíček, DOPAS training workshop course leader	CTU, Czech Republic
Jacques Wendling, Performance assessment of Andra's programme	Andra, France
Régis Foin, FSS experiment leader	Andra, France
Jiri Svoboda, EPSP experiment leader	CTU, Czech Republic
Pär Grahm, DOMPLU experiment leader	SKB, Sweden
Petri Koho, POPLU experiment leader	Posiva Oy, Finland
Lucie Bělíčková, Prague and Rez organization	SURAO, Czech Republic
André Rübel, Safety and performance assessment, WP5 leader of DOPAS	GRS, Germany
Dean Gentles, Application of lessons to other waste management programmes, WP4 leader of DOPAS	RWM, Great Britain

Tab 1: Planning group of the DOPAS training workshop

The planning approach was based on producing a complete action cycle for the learners based on Kurt Lewin's concept (1) and on the philosophy of Dewey (2). This concept has been further applied to training and represented in Kolb's Learning cycle (2). This same concept was used as the basis of Deming's wheel PDSA[2] (3), too, well known to people engaged in quality management and the implementation of ISO 9000 based quality systems (4). The application of Kolb's cycle in learning can start at any point of the cycle as long as the whole cycle is included in the learning process. In addition to this guideline, the training emphasized the need to combine both theoretical and practical activities carried out in small groups. The purpose was to ensure that the participants could learn knowledge, skills and competences (KSC) during the process. In the same way, the learning outcomes were defined by setting up the training from four main learning units following the ECVET (5) approach.

One of the main planning decisions made was to emphasize two themes in the training. First, the aim was to give the participants an orientation to reflect on the purpose of the plugs and seals and the time that is applicable to the plugs and seals and for their needed isolation and containment function. These vary significantly among the various plugs and seals depending on the repository safety concept and on the host rock environment. In addition, the training order was planned in such a way that each of the learning outcomes was presented first by introducing one experiment in detail. This was then followed by shorter introductions related to the other experiments and with an exercise or activity requiring the participants to apply what they had just learned. The approach aimed to provide the participants themselves an opportunity to start to identify and contrast the differences between the choices made for the five different DOPAS experiments and to understand the underlying reasons for the differences. One of the feedbacks from the participants confirmed the usefulness of this approach in creating increased interest in the participant to gain more knowledge about the national programme and in being able to assist in the programme by using the learning outcomes.

The expected Learning Outcomes (LO) for the participants were

- To understand the process/es of designing a full-scale experiment from a set of requirements related to the performance of the safety function/s of a plug or a seal as a repository component in geological disposal.
- To be able to contrast the differences of such processes resulting from the different

[2] "Plan, Do, Study Act" cycle

boundary conditions e.g. from the host rock environments (clay, crystalline rock, and salt), the experimental settings (above ground, underground experimental facilities vs. real repository conditions) and other site and disposal concept specific features.

- To comprehend the linking of different experiment project's related subprojects and tasks and their inputs and outputs as a part of the experiment implementation.
- To acquire hands-on experiences in experimenting with materials' testing and monitoring techniques needed in an experiment, and
- To know how the individual experiments and their outputs contribute to the overall demonstration and demonstration programmes for safety of the waste management programmes at the different stages of repository development.

The training design included four main Learning Units (LU) consisting of a total of 10 topics that were related to the desired Learning Outcomes (LO):

Learning Unit 1: From requirements to the design basis of plugs and seals (DAY 1) including

Understanding requirements management and their application for plugs and seals design basis

- The purpose of plugs and seals in clay
- The purpose of plugs and seals in crystalline rock
- Requirements - understanding and applying them (sources, requirements as a system)

The Design Basis development work flow for plugs and seals - Application of requirements management system to plugs and seals and developing a design basis from them.

- Developing a design basis for an experiment
- Case Example of the Czech experiment EPSP
- Scoping the DOMPLU experiment. Moving from the initial design to an experiment in place including Exercise 1

Learning Unit 2: Preparation of an in-situ or full-scale plug or sealing experiment (DAY 2)

How to come up with a coherent demonstration program for plugs and seals?

- Theoretical basis to Andra's iterative safety assessment process and the latest safety assessment round
- Actual case example about the last round of safety assessment iteration in Andra's demonstrator programme in clay (FSS) - Explicit description of the last iteration cycle

The role of instrumentation and monitoring in an experiment including the Exercise 2 (sensors, their installation and analysis of results)

Monitoring for performance assessment of experiment components (Thermal processes, Exercise 2 continuation) (DAY4)

Learning Unit 3: Design of a seal for an experiment/ demonstrator within the broader context of RD&D programmes (DAY 3 - DAY 4)

What is the state of the art in the demonstrator (RD&D) programs today?

- Andra's scientific programme and its current state. The main questions replied to for the next safety assessment report (DAC[3] 2017) and after the submission of DAC?
- Plugs as a part of the demonstration programmes in Nordic countries (YJH[4] and FUD and in the stages of licensing) - including alternatives

Behaviour of plug components and materials

[3] DAC = Demande d'Autorisation de Construction French construction license.

[4] YJH = 3 year Finnish R&D programme plan, FUD = 3 year Swedish R&D programme plan for nuclear waste management

- The use of individual tests to complement existing material and process knowledge (case of REM[5] metric experiment)
- Instructions for laboratory Exercises 3-4 on material behaviour at UJV Rez a.s.

Introduction to Safety Assessment and integration of the experimental work and process modelling in the safety assessment/ safety case.

Learning Unit 4: Construction Feasibility of a plugging experiment (DAY 4 and DAY 5)
Practical underground work concerns in setting up an in-situ or full-scale experiment

- Risk management for large-scale experiments and work underground
- Case example of POPLU experiment (recipe development, method tests and casting, start slot location + RSC[6] and design; moving into real repository construction, as built vs. design) and related exercise on identifying and prioritizing risks for full-scale experiments
- Feasibility of a seal in a clay rich host environment. How to adapt the technological process including alternative concept/s
- Working methods underground and for experiments
- Lessons learned from the experiments until today - Panel on experiences, constraints and lessons learned

How to further apply the lessons learned for the future

- The use the DOPAS experiences in a waste management programme not yet in the demonstration stage or without a site - Case of RWM
- Preparing for ELSA experiment.

The different learning units were tied together with more general activities like general presentations on DOPAS, Josef facilities and on the Czech geological disposal programme. The planning group members took turns in chairing the different training days during the week and at the same time triggered discussion in the training group on the topics at hand. The planned exercises included group work on experiment project management, risks, hands-on production and installation of sensors into the underground facility, handling and interpretation of the measurement data, laboratory tests related to cement bentonite interaction and uni-axial testing on material samples for identifying strength and failure mechanisms.

During the last day, the participants were given an opportunity to interview the tutors in a closing panel focusing on the lessons learned from the DOPAS experiments. In addition, the day included a self-assessment by the group on how they had attained their objectives for the training.

3 Implementation of the DOPAS training workshop

The training workshop was advertised on different venues and using contact lists of the planning group in the waste management community and universities and relevant websites in addition to the DOPAS website were used. These websites included e.g. the IGD-TP (www.igdtp.eu) and the ENEN association (www.enen-assoc.org) sites. The number of participants to the training workshop was limited to 12 persons. The training workshop was not oversubscribed, but some last minute cancellations enabled the participation of few more participants who had been alerted to this opportunity only after the registration closing.

The participants came from Czech Republic (3 persons), Finland, Germany (2 persons), Great Britain, Hungary (3 persons), Poland, and Sweden. Four of the participants were

[5] REM = resaturation test related to the FSS experiment clay materials by Andra
[6] Rock Suitability Classification

active students in the German and Czech universities, at the same time they were working at various organizations. Seven of the participants came from consulting or engineering organizations, two came from waste management organizations and the rest from an authority and research organizations and universities. All of the participants had a scientific or technical background, with most of them with a background in geotechnical engineering or geology.

The training materials were distributed to the participants via a protected internet site for downloading prior the start of the workshop. The materials consisted of about 40 different presentations, of five major exercises and of other supporting materials, presentations of the tutor organizations and of the documentary movie "Into eternity" by director M. Madsen shown at the courtesy of the producer Magic Hour Films of the movie.

The first training day took place in Prague at the CTU. The purpose of the day was to provide the training participants an orientation to the training topic and at the same time to get them acquainted with each others. The content focus was on the requirements and design basis of plugs and seals and on their purposes. The practical experiments included the presentation of the Czech and Swedish plug experiments, EPSP and DOMPLU. The introductory day's short exercises in pairs and small groups promoted the participants to get to know each other for supporting and open minded cooperation during the workshop.

The second day continued at the Josef facilities with the presentations about the interactive process of safety assessment in the case of Andra and about the role of the FSS experiment in it. The training also included an introduction to the Josef facilities, the role of monitoring and instrumentation in the experiments, and a hands-on exercise in preparing thermal sensors and their installation into the Josef underground into the vicinity of the heater assigned for this exercise purpose. The data was then collected and interpreted during the fourth day when the training group returned to Josef again.

Fig 1. "Who has experience with soldering?" Day 2 practical exercise on sensor making in one of the groups.

Photo: Marjatta Palmu, Posiva Oy

Fig 2. "Let's put the sensors in place" at Josef Underground Laboratory. Photo: Marjatta Palmu

The third day started at UJV Rez a.s., where practical works continued after the presentations about the French and Nordic research and development programmes where the experiments are on part of the planned work. The work continued at the UJV Rez laboratories with the practical exercises. After the laboratory exercises the group moved to the SURAO information centre in the centre of Prague. The focus was on the Czech siting programme and on stakeholder communication. The evening ended with a "movie night" and discussion related to the "Into eternity" documentary.

The fourth day took place in Josef again. The content focused on the general principles of safety assessment and on the technical feasibility of the plug and seal construction. Presentation of the POPLU, DOMPLU and FSS plugs' construction works were given and the participants worked on identifying the potential risks related to the experiments in the Nordic countries. The second part of the long day at Josef was spent in analyzing the sensor data from the sensors installed in the heated rock. Finally, the day was finished with a visit to the Josef cathedral with Czech music and the light show.

Last training day brought the group back to Prague, where the participants learned about the German ELSA experiment and related materials, about how RWM aims to use the lessons learned, and the experiments' lessons learned were summarized in a tutor panel. The afternoon was filled with the participant presentations on the outcomes of their exercises during the week. They received feedback from the various tutors on their findings. The groups sent their exercise reports to the tutors after the training course and were given a further evaluation of their work, too. The day and the official training course finished with the participants assessment on their attainment during the week. In practice, beautiful Prague saw still a group of enthusiastic training participants enjoying their last night in the golden city.

4 Assessment of the DOPAS training workshop

The participants' activities and interaction was observed during the whole week. The group worked very well together and assisted each others in the exercises. All wanted to perform their tasks very well and if they felt that they had not reached the target they had set, the felt a bit disappointed. Each exercise carried out was followed by both the peer assessment of the other group's outcomes compared with the group's own results and complemented with the tutor/s' feedback.

In the beginning of the workshop the participants set their own expectations and goals for the training (see ref. 6, p.4) and most of their objectives were achieved. In addition to the group assessment, the participants also gave their individual evaluation of the workshop on an evaluation form. The outcomes of the evaluation varied on a scale from 1-5 between from 4.3 to 4.8 on average on nine different evaluated items. Replies were received from all participants. The tutors made a similar evaluation independently and came to the same conclusion as the participants.

D - Demonstrative

O - Optimistic

P - Positive

A - Accurate

S - Serious

DOPAS Training Workshop 2015 as described by one of the participants.

Entering Josef cathedral. Photo: Marjatta Palmu

Fig 3. DOPAS Training Workshop 2015 participants and tutors

The participants received a training workshop diploma with a recommendation letter from the workshop organizers supporting the recognition of the amount of work done in the workshop to equal four ECTS for academic studies.

The outcomes of the training workshop are planned to be documented using the ECVET approach in the form of KSC needed for each of the learning units and related learning outcomes before the end of the project. This documentation is intended to make it easier for any future users of the training material to apply it using the similar principles and approaches in their training.

5 Conclusions and acknowledgements

The workshop was successfully implemented and well received from both the participants and the tutors. The planning process also assisted in structuring the connections of the DOPAS work for the tutors engaged in the process and this contributed also directly to the planning of the expert elicitation of the DOPAS work package deliverables. Much work was done to produce the plan and to implement it. We hope that when the training workshop report comes out, also other trainers find the materials useful and use them in future training.

Defining and implementing the workshop content according to ECVET tools was beneficial for both – the participants and organizers - as this course provided first opportunity to experience and use the ECVET approach for many of them.

Special acknowledgements go to all the tutors and the members of the training workshop planning group and to Nagra contributing their materials for the training and to other DOPAS consortium members.

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7 DOPAS specific abbreviations

DOMPLU	Dome Plug deposition tunnel plug experiment carried out in Äspö Hard Rock Laboratory in Sweden by SKB in collaboration with Posiva
DOPAS	Full-scale Demonstration of Plugs and Seals, Euratom FP7 Framework project
EPSP	Experimental Pressure and Sealing Plug experiment in Josef Underground Laboratory in Czech Republic

FSS	Full-scale Seal experiment in St.Dizier France
POPLU	Posiva Plug wedge shaped deposition tunnel plug experiment in ONKALO underground rock characterization facility in Finland by Posiva in cooperation with SKB.
ELSA	Entwicklung von Schachtverschlusskonzepten (development of shaft closure concepts) related tests and future experiment in Germany

For further explanations please visit http://www.posiva.fi/en/dopas.

CONSIDERATIONS ON NEW STUDY PLANS FOR HIGHER EDUCATION IN NUCLEAR ENGINEERING AND RADIOPROTECTION

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ABSTRACT

Many countries have introduced important changes in curricula of Universities and other Education Institutions. Study Plans on Nuclear Engineering and Radioprotection have been also widely modified. The number of courses have been highly increased. At the same time, students are allowed to choose many free election courses, which makes difficult to have a more flexible timetable for lectures. It can also produce a decrease in the number of students per course. With the choice of courses completely free, the formation of students on nuclear fields is apparently not improved, since an optimal curriculum on Nuclear Science and Technology cannot be easily configured. How to encourage new generations to choose the nuclear option? The concentration of specific courses at Master level could improve education and training of good engineers and scientists in nuclear fields. On the other hand, the use of active learning methodologies is highly recommended in new Study Plans as it can improve the formation of students. The student should be the active subject of his own learning. Teachers should supervise and direct this learning process to optimise teaching results. It is thus necessary to involve students in the development of lessons being indispensable their personal motivation. The situation both general and particular for nuclear courses is analyzed with a special attention to the situation at the Polytechnic University of Valencia (UPV) and some solutions are proposed. Three sectors should be involved in the process to improve the situation. National Governments developing new Study Plans and International Agencies giving suggestions will contribute to improve it. Universities and Higher Education Institutions should correctly apply these plans. And companies related to the nuclear sector should actively collaborate to a better education and training in nuclear technologies.

1. Introduction

Many countries have recently introduced important changes in curricula of University studies and other Higher Education Institutions. In particular, Study Plans on Nuclear Engineering and Radioprotection have been widely modified. This situation affects students going through nuclear courses, but it is necessary to encourage new generations to choose the nuclear option.

Increasing the number of free-election courses makes difficult to have a more flexible timetable for lectures. Dispersion of attention among different matters is not good for the education and training. Therefore, an optimal curriculum on Nuclear Science and Technology cannot be easily configured. On the other hand, the use of active learning methodologies is highly recommended as it can improve the formation of students.

In this paper, the general situation and particular features of nuclear related courses are analysed with a particular attention to the case of the Polytechnic University of Valencia (UPV). Finally, some solutions are proposed for the problems arisen in courses like Radioactive Protection and others.

2. Present situation of nuclear field.

The question about how to encourage new generations to choose the nuclear option has to be considered not only in the environment of new Study Plans, but also in the context of the general present situation of the nuclear energy. Various external factors can influence on the decision of new generations of students about the nuclear option.

The negative impact, in general, on the public opinion of the nuclear energy is well known. The atomic science is well accepted in the medical field, but not for energy production, which is necessary for the modern style of life. When the impact of the Chernobyl accident was disappearing from the scene, it occurred the Fukushima accident.

Germany decided a schedule to close all of its Nuclear Power Plants (NPP). France is wondering if the nuclear option can continue with advanced reactors or modular ones, even sharing nuclear with renewable energies.

Present economic thinking are quite unstable and the nuclear field demands a long-term economic model. Lower power reactors (modular reactors) permit a better management of safety issues, but they are more expensive. There is no problem to extend the reactor life provided an authority with appropriate legal tools can order shutdown if the safety is downgraded. In some countries with a large capacity of economy planning, the nuclear sector is well developed and does not present major problems, which does not occur in countries with an ultraliberal model [1, 2].

The generation of nuclear engineers and scientists who projected and worked in the construction of NPPs in operation is going to retirement in the next years. It is indispensable to replace them. Therefore, a good program for nuclear matters in universities is essential as well as a planning of education and training in companies working in the nuclear sector.

3. Situation in new Study Plans at UPV

3.1 General features

Nowadays, Study Plans at UPV include 14 undergraduate degrees (Bachelor level) and 9 Master degrees, but not all of them have professional attributions of Master Engineer. Normally, to get them it is necessary to obtain a Degree diploma after 4 years (240 ECTS) plus a Degree Thesis followed by a Master that encompasses 2 years (120 ECTS) plus a Master Thesis.

Each degree and master program has several different specializations with a lot of optional courses. This means a high increase in the number of offered courses. Furthermore, there is an almost completely free choice of optional courses, whose number is higher than in previous Study Plans. Consequently, the organization of lectures is quite difficult with a negative impact on the schedule of students and professors. Obviously, studies on Nuclear Engineering and Radioprotection become also affected by these changes in new Study Plans.

3.2 Nuclear related courses

We can put aside some courses included in the Degree of Biomedical Engineer such as Radiotherapy and Radiological Protection, or Imaging Techniques. It is also given Nuclear Physics as part of Physics III in 2nd year of the Degree on Energy Engineer. In the 4th year of

Chemical Engineer Degree there is an optional course on Nuclear Chemical Technology, and in the 1st year of the Chemical Engineer Master, 12 hours about nuclear reactors are included in a course encompassing different chemical reactors.
The courses we are interested in are located in the 4th year of Energy Engineer Degree (GIE) and 2nd year of Industrial Engineer Master (MII). A course on Nuclear Technology is compulsory in the first semester of 4th GIE. A similar course entitled "Nuclear Energy and radiations" is also compulsory in the first semester of 2nd MII. The second semester of 4th GIE offers 4 optional courses: Advanced Nuclear Plants, Reactor Operation, Radiological Protection, and Nuclear Safety. There is an optional course entitled "Radiological Protection in Radioactive and Nuclear Installations" in second semester of 2nd MII. Really, they are two different studies and graduates in Energy Engineering cannot follow the Industrial Engineer Master.

The problem appears when students of 4th GIE choose their optional courses. Regulations permit that students have a high grade of free election courses, which makes difficult to have a more flexible schedule for lectures. A student usually chooses, for instance, 1 or 2 of the optional courses; rarely all of them. There are two important consequences: the formation of students becomes incomplete in the nuclear field and there is a decrease in the number of students per course. With the choice of courses completely free, the formation of students on nuclear fields is apparently not improved. Therefore, an optimal curriculum on Nuclear Science and Technology cannot be easily configured.

It is missing a Nuclear Energy Master or maybe an Energy Master, more general, but including a nuclear option. By this reason, among others, students after finishing GIE should move to another institution if they want to complete their studies with a master on Nuclear Energy.

4. Possible solutions

How to encourage new generations to choose the nuclear option? Dispersion of attention on non-related subjects is not good for the education and training from a global point of view and also for the formation in the nuclear field. Then, a well-structured planning for the Energy Engineer Degree with a specific Master on Nuclear Engineering is required.

A possible solution to the problem could be the concentration of specific and specialized courses at Master level while introductory and basic courses are left at Bachelor level, where different branches can be presented. This probably could help to have good engineers and scientists in nuclear fields.

Of course, the teaching methodology applied in these courses may have a positive impact on the learning process as well as on the disposition of students to choose the nuclear option.

Three sectors should be involved in the process. National Governments developing new Study Plans and International Agencies giving suggestions will contribute to improve the situation. Universities and Higher Education Institutions should correctly apply these Study Plans. And companies related to the nuclear sector should actively collaborate to a better education and training in nuclear technologies.

5. Methodology

The use of an active teaching methodology is highly recommended as it can improve the formation of students. However, the active methodology is not just to increase the number of exams (e.g. one per month) and to program in all details the activity to be developed by students.

The active learning methodology developed for courses on Radioactive Contamination, Nuclear Engineering, Radioactive Protection and related matters has been presented at previous conferences [3, 4, 5].

The student should be the active subject of his/her own learning. Professors and lecturers should supervise and drive this teaching process to optimise learning results. It is thus necessary to involve students in the development of lessons being indispensable their personal motivation.

The issue is to encourage students to actively participate in class by discussing each lesson, although they have no background in the field. The objectives of each lesson are proposed by means of questions to stimulate the participation of students in the discussion.

The questions should be addressed to obtain ideas from students not just to get answers read in a book. The best quality of the professor should be to stimulate students while the best quality of students is to think together with to work.

Obviously, students must be previously provided with the information necessary to prepare the discussion. This information can include notes about the matter [6, 7], bibliography, practical exercises, questions, software and web pages. Students can also use different books, journals or websites to complete the study of the lesson. A text book covering the major parts of the course can be a powerful tool to reach the proposed objectives [8, 9].

The evaluation (preferably continuous) of students should take into account the comprehensive understanding of basic concepts and their application to practical cases, verifying the accomplishment of objectives. The development of individual projects with an oral presentation should be stressed.

When there is a high number of students per course it is more difficult to apply this active learning methodology. In that case, e-learning (partial or total) could be used. However, the direct contact teacher-student is a bit lost with e-learning and this fact should be compensated in some way as it is important to keep active this contact as much as possible.

6. Conclusions

New Study Plans for Higher Education in Nuclear Engineering and Radioprotection have a possible negative impact on the formation and training of engineers and scientists in nuclear fields.

It is necessary to decrease the optionality of courses to avoid the dispersion of the attention and to get a more complete formation of students.

It is very convenient to establish a program of basic courses at Bachelor level for energy engineers followed by a well-structured Master on Nuclear Engineering.

An active learning methodology is highly recommended as it can improve the formation of students. The self-learning should be stimulated trying to maximize the thinking activity of students.

A common action to improve the situation must be taken in three sectors: institutions elaborating Study Plans, universities and companies involved in the nuclear sector.

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ENHANCING NUCLEAR SAFETY CULTURE TRAINING THROUGH KNOWLEDGE MANAGEMENT AND EMERGENCY RESPONSE EXERCISES

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ABSTRACT

The University of Utah Nuclear Engineering Program (UNEP) has established and continues to build a strong nuclear safety culture by developing class and laboratory soft skills training and activities. An effective safety-culture is essential to nuclear safety and can help prevent errors and misconduct by ensuring expectations and consequences are clearly stated and understood. Academic and research reactors present additional challenges as new students are joining the program and nuclear environment for the first time.

A dynamic learning activity (DLA) that was presented in 2013 NESTet Conference as being designed has been implemented and carried out for the last two years helping establish the nuclear safety process to all incoming and new students. Students involved with laboratories and classes in UNEP receive training with the expectation that everyone is responsible for documenting deficiencies or areas for improvement and entering them in the DevonWay, corrective action tracking software.

The DLA contains training on Human Performance Error Reduction techniques that are used in the industry such as STAR (Stop, Think, Act, Review), critical steps, verification techniques, procedure use and adherence, and communications. Another important aspect that is presented in the DLA is proper methods of coaching that should be implemented in the nuclear environment. The successes and lessons learned from presenting the DLA to students is discussed.

To meet the training needs of the newer generation of nuclear engineers, a new style of emergency response training is being conducted on prospective reactor operator licensee students in our Program. Instead of the standard lecture format for learning emergency response procedures for the reactor facility, the students are tasked with designing, developing and carrying out emergency plan drill scenarios. The style of the student studying on their own and then implementing both scenarios and proper responses ensures an adequate and thorough understanding of the emergency response plan.

UNEP is also focusing on knowledge management and retention for students in the nuclear industry using the adaptive corrective action program software, DevonWay. UNEP has customized DevonWay to serve the purpose of a knowledge management and retention tool between students progressing through the degree programs.

A new generation of nuclear engineers and technicians need to be trained to meet the needs of the nuclear industry. The current nuclear workforce is nearing retirement and as they retire, they will take with them a large amount of experience and knowledge. New methods to meet the needs and styles of learning for the younger generation need to be developed and employed to fill the nuclear workforce void. The new generation of nuclear workers are used to being connected with technology but have a limited background with lessons learned and what makes nuclear different and special. Establishing a strong nuclear safety culture is a vital part of the process for training the new nuclear workforce. UNEP is meeting the needs of the nuclear industry by implementing novel educational approaches to train the new nuclear workforce with the safety-culture mindset needed to ensure continued safe nuclear operations.

1. Introduction

In assessing the 1986 Chernobyl accident, the International Atomic Energy Agency (IAEA) coined the phrase ‘safety culture’ [1]. Since that time, the majority of all major nuclear related accidents have sighted the lack of nuclear safety culture as a contributing cause. The U.S. Nuclear Regulatory Commission (NRC) has defined safety culture as “the core values and behaviors resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals to ensure protection of people and the environment” [2].

UNEP has established and continues to build a strong nuclear safety culture by developing class and laboratory soft skills training and activities [3], [4]. An effective safety-culture is essential to nuclear safety and can help prevent errors and misconduct by ensuring expectations and consequences are clearly stated and understood. Academic and research reactors present additional challenges as new students are joining the program and nuclear environment for the first time. At UNEP we manage, operate and maintain close to 7,000 sq. ft. facility laboratories including a 100 kW TRIGA Mark I reactor and seven state-of-the-art radiation counting stations, radiochemistry, nuclear forensics and nuclear medicine related laboratories. All labs and the reactor facility are jointly managed under the DevonWay corrective action program (Track & Trace software intelligent system adapted to our facilities) [5], [6]. Additionally, our undergraduate and graduate curricula both incorporates education and training on safety culture and corrective action program in providing a sustainable set of educational practices with hands-on learning.

As part of the safety culture improvement process, UNEP has been working on and has implemented a safety culture DLA, emergency response training, and a new nuclear knowledge management software based approach.

2. Safety Culture Dynamic Learning Activity (DLA)

A dynamic learning activity (DLA) has been implemented at the beginning of all semester classes and laboratories to introduce and establish the nuclear safety process to all incoming and new students. Students involved with laboratories and classes in UNEP receive training with the expectation that everyone is responsible for documenting deficiencies or areas for improvement and entering them in the DevonWay, corrective action tracking software.

The DLA contains training on Human Performance Error Reduction techniques that are used in the industry such as STAR (Stop, Think, Act, Review), critical steps, verification techniques, procedure use and adherence, and communications. Another important aspect that is presented in the DLA is proper methods of coaching that should be implemented in the nuclear environment.

Finally, hazard identification and practical exercises have been developed to test the students’ comprehension and internalization of concepts presented in the DLA. Example scenarios are set up in the laboratory environment as seen in Figure 1 and students must identify hazards and demonstrate proper coaching techniques in order to pass the activity and be permitted to conduct research in the facilities. The students are also timed for how long it takes them to identify the hazards. Then at the end of the semester they are given a more difficult scenario and again timed for how long it takes them to identify as many hazards as possible.

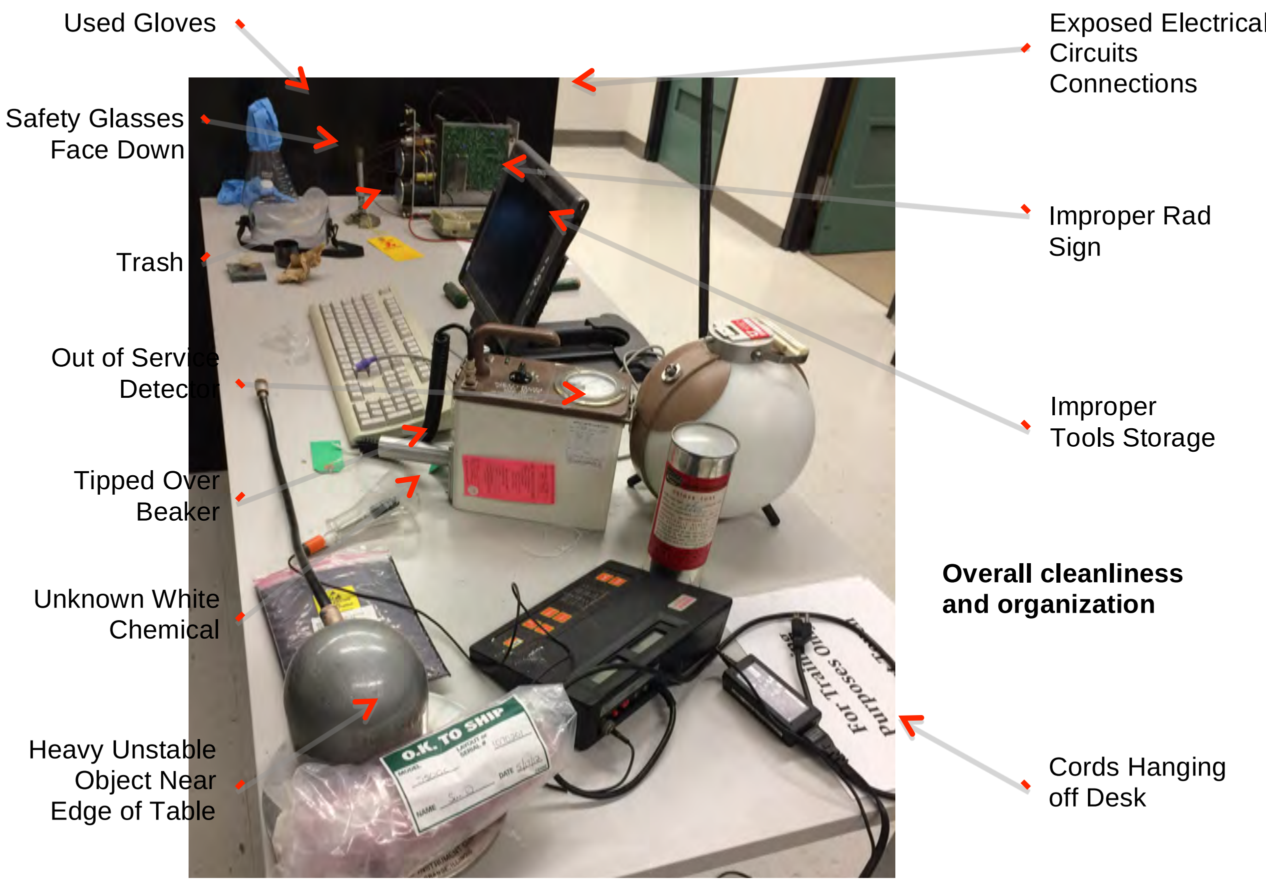

Figure 1: Safety DLA Practical Work Station Setup used at the end of Fall 2015 Semester with 15 deficiencies to train students in hazard and deficiency identification

During the first two years of implementing the DLA the results have demonstrated that the students were able to identify more safety issues and in a timelier manner after completing the course and DLA training sessions. Results from the last four semesters are shown in Figures 2 and 3. Figure 2 shows that at the beginning of each semester 8-9 deficiencies were inserted where at the end of each semester the number of deficiencies was increased to 14-16. The percentages seen on Figure 2 show the accuracy of how many deficiencies were identified by the students. In the beginning of the semesters the students identified 61%-72% of the deficiencies whereas at the end of the semester 80%-85% of the deficiencies were found. Figure 3 shows the time required for the students to identify these deficiencies. It can be seen that at the beginning of a semester the students spend approximately 8-9 minutes in identifying 8-9 deficiencies, while by the end of a semester a marked improvement is found with 4-5 minutes spending to identify 14-16 deficiencies.

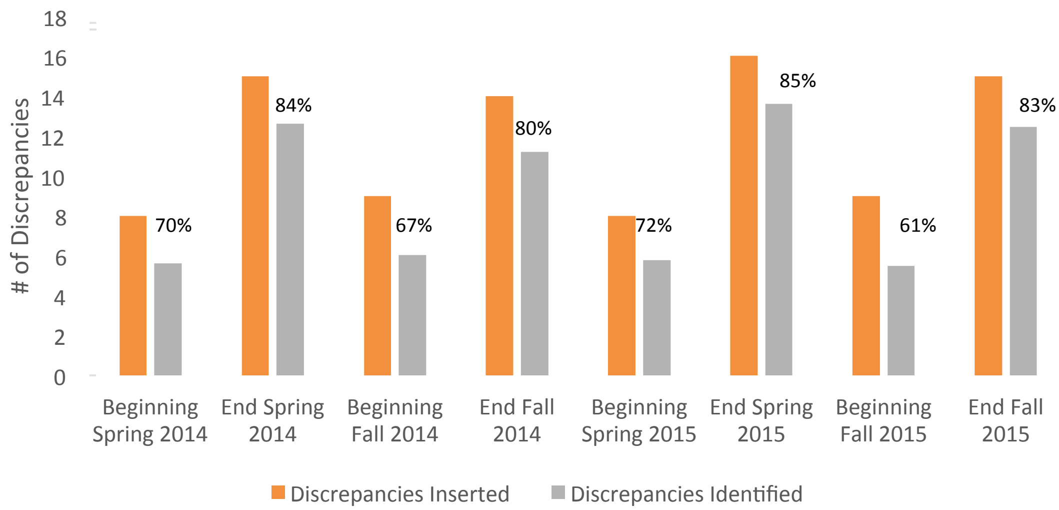

Figure 2: Safety DLA Discrepancy Identification 2014-2015

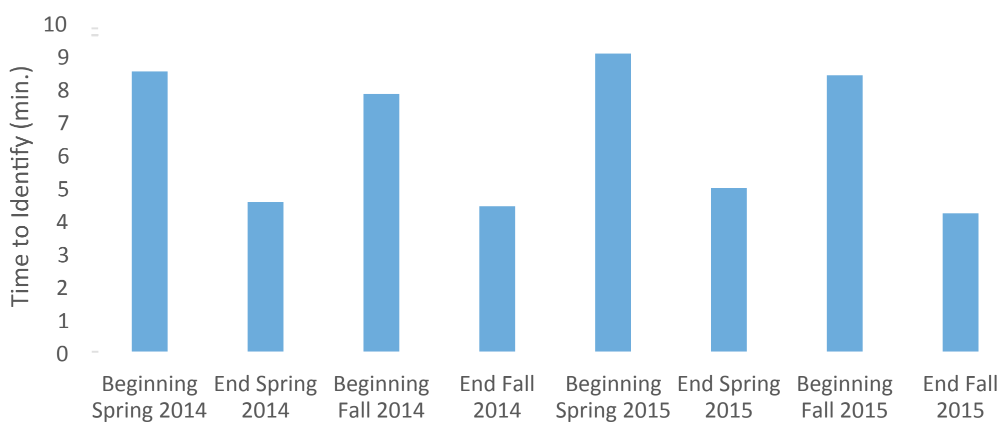

Figure 3: Safety DLA Time to Identify Discrepancies 2014-2015

3. Emergency Response Training

UNEP is required by U.S. NRC standards to conduct emergency response drills each year. For many years the same earthquake drill was used each year. This resulted in minimal training and lesson learned experiences. As part of the UNEP program, students can take a yearlong course to obtain their reactor operator license training and then be examined by the NRC to receive the NRC issued operator or senior operator license. As part of this class, all students must learn the emergency response procedures and actions. It was found that the students did not internalize much of the information on emergency response if given in a lecture format. Recently, UNEP has implemented an innovative technique in teaching emergency response training described as follows.

Instead of lecturing about various emergencies and their response, students are given the emergency response plan and challenged to develop new drill guide scenarios for various emergencies associated with the facility. This requires the student to become familiar with the procedure by choosing and reading what the response should be for their given scenario. This also requires the students to have a more thorough understanding due to them writing about the expected responses and possible deviations.

The drill guide scenarios include sections on the following:

- Initial Conditions
- Pre-Drill Notifications
- Precautions and Limitations
- Operational Limits
- Technical Safety Requirements
- Drill Team Duties
- Evaluators
- Safety Monitors
- Drill Initiation
- Expected Response
- Evaluation Criteria
- Termination and Restoration

The completed scenarios are then reviewed and approved by the UNEP staff and leadership. After the scenarios are approved, the drills are actually conducted on the other students in the class. The student that drafted the drill guide then grades and critiques the other students. This experiential learning has been much more effective and the knowledge of the emergency plan has been a strength for those students taking the license NRC exam.

The students have taken a great interest in making the scenarios as realistic as possible and the program has found areas for improvement while conducting the drills. Some example scenarios are hostile action against operators, suspicious package and injured/contaminated individual. Figures 4 and 5 show pictures of a drill for a suspicious package that was conducted with local bomb squads and the US FBI. The local agencies brought robots and all agencies benefitted from the experience. In this specific student designed drill, a few armed men stormed the UNEP facility and gained access to the reactor room. They were then engaged by University Police and the police found a suspicious device in the reactor room as seen in Figure 4. The suspicious package contained a Cs-137 source to test the bomb squad's robot ability to detect and monitor radiation levels. Three FBI special agents, four University of Utah Police Officers, one Radiological Health Department Technician, eight Salt Lake City Bomb Squad Officers, and eight students and staff members of UNEP participated in the drill. The UNEP staff and students obtained lessons learned on how to communicate with multiple agencies and the bomb squad found some limitations on being able to see certain sensor displays on their robots in low lighting areas.

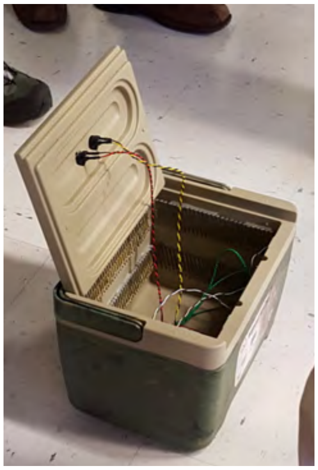

Figure 4: Suspicious Package Figure 5: Bomb Squad Robot and Equipment

4. Innovative Nuclear Knowledge Management Program

The UNEP has implemented a corrective action program (CAP) since 2010 using the DevonWay intelligent software [5]. DevonWay software is in use by over 80 nuclear power plants in the U.S. industry to meet their CAP needs [7]. The software is web-based and hosted by DevonWay in its certified data center. The UNEP version of this software is also being used to track purchasing and maintenance processes. Students are well prepared to enter the workforce and understand the corrective action process and be able to immediately add value to their organization of employment being trained under the UNEP CAP system.

The DevonWay software is very simple and easy for new users to understand. It also is very flexible, easily customizable and web based. Due to these characteristics, UNEP has chosen to use the DevonWay software as a tool to develop a new approach to the nuclear knowledge management for the program.

In a university and academic programs, new students are constantly joining the program, while other students are graduating and leaving for employment opportunities. In order for new students to continue on with research that has already been in progress by graduating students and not loose valuable time, a robust and intuitive nuclear knowledge management program is therefore needed.

Currently, as part of the process for graduating students, they must carefully catalog and document their research and describe the methods they used for software or other experimentation in the DevonWay software. There is a module for graduating students that prompts them to document various parts of their research. Once it is input, other students can search and find the needed documentation. The DevonWay software is searchable in a similar way to google. This allows for the new student to easily find and build upon previous students' work. Attachments can also be uploaded (such as the thesis or other pertinent documents) and many different file types are supported. The DevonWay software will even convert most documents to a .pdf type file if the user doesn't have the software for the matching document. Figure 6 displays the screenshot that students are provided while entering their work for a nuclear knowledge transfer.

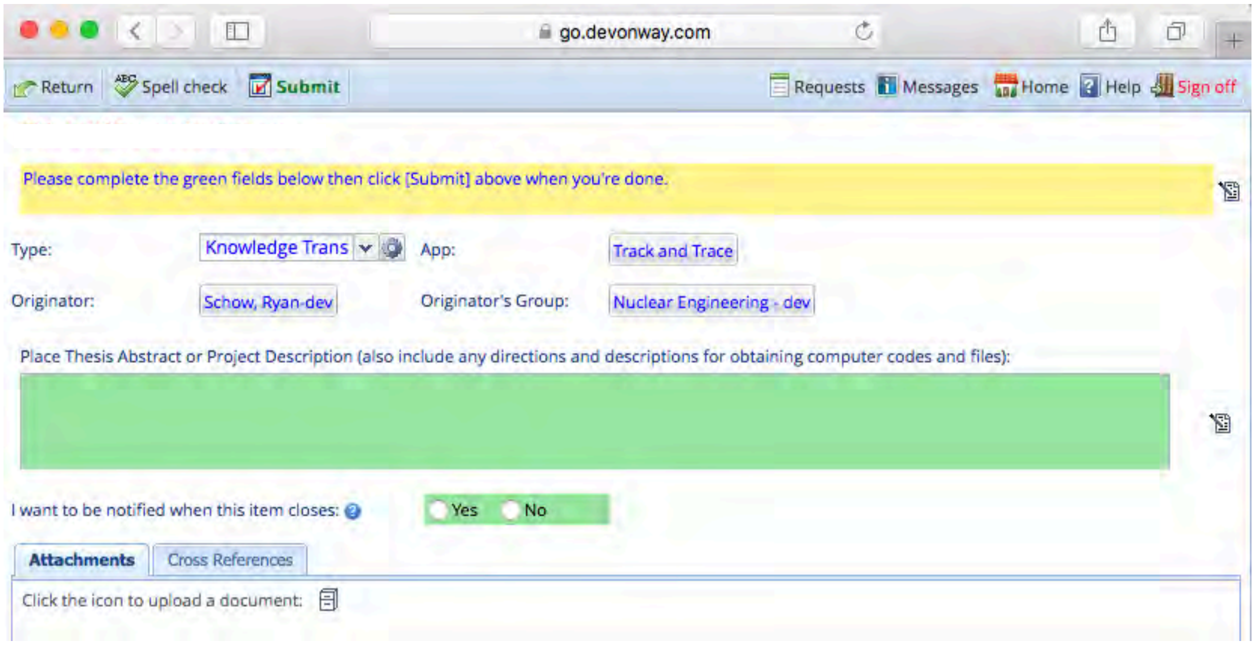

Figure 6: DevonWay Software Nuclear Knowledge Transfer Entry Screenshot

5. Conclusion

UNEP has been implementing new and innovative tools to help improve and ensure nuclear safety culture and nuclear knowledge management at the nuclear engineering facility. By implementing new teaching styles such as students developing and implementing emergency response drills to expecting all students to identify and report hazards found in the lab environment, new techniques have been tested that can be used in various settings. The knowledge management program supports the effective safety culture, facilitates innovative ideas, enhances performance of students, and improves organizational effectiveness. UNEP has recently been collaborating with different countries and industries with regards to safety culture. In March of 2016 UNEP hosted the 1st Symposium on Engineering Safety Culture and Innovations and also participated at Okayama University's 8th Symposium on Environmental and Energy Issues in November 2015 [8], [9].

The graduates from UNEP that are entering the nuclear engineering workforce are prepared with many of the skills that are needed to keep nuclear engineering safe. The nuclear safety culture that is taught from day one to all students and members of the program is ingrained to a level that will be taken to their future work places.

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HELPING TO DEVELOP EFFICIENT COMMUNICATION SKILLS IN NUCLEAR ENGINEERING COURSES

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Abstract

Efficient Communication is usually pointed out as a valuable skill for engineering companies. However, teaching efficient communication skills is normally not a first order priority in engineering schools in Spain. There are optional courses to learn how to speak in public or to write correctly, but in general these haven't been considered as core subjects in the curricula. Initiatives like the EC-2000 have been made in order to change this situation.

In the subject of Nuclear Power Plants taught in the Technical University of Madrid (UPM), the capability of efficient written and oral communication has been included as an evaluable skill during the last courses. In this subject, the capability of efficient communication, has been evaluated according to the EC-2000 initiative (Section 3g of ABET). Firstly, during the course there were specific lessons in which the attitude and actions of a good presenter and writer were discussed and explained. Secondly, the communication skills were evaluated during the subject.

Each student was assigned to an advanced reactor for a written assignment and a technical presentation. The written skills were evaluated with the written assignment, they had two scores on the assignment, a technical and a written skill score. The oral skills were valuated during a technical individual presentation where there were two evaluators: one for the technical part and the other for the communication skills. The communication skills evaluator assigned a qualification from 0 to 5 to several aspects observed during the presentation. The main aspects were: visual contact with the public, voice modulation, adequate gesture, good manners during questions and adequate presentation organization. The average qualification of all these actions were the score on efficient oral communication.

There was a correlation between a good score on the technical level and the communication skills. This may imply that a good student learns and understand oral and written communication techniques just as he or she can understand technical information.

1. Introduction. The EC-2000

Efficient communication, oral and written, is a transversal competence included in the Technical University of Madrid (UPM) study program. This skill has been previously evaluated by initiatives like the EC-2000, [1] which is the reference for the present project.

The EC-2000 establishes certain aptitudes or abilities that are supposed necessary for a student in the moment of finishing the course. When this accreditation criteria was adopted, the engineering schools had to develop and implement continuous improvement programs and procedures that certify that students had specific aptitudes. These aptitudes are related with applying knowledge and modern tools to engineering tasks, being able to adopt the leader role in a team, or the understanding of the ethical responsibilities that involve future jobs.

One of those aptitudes is the efficient communication ability. This aptitude is evaluated by the accreditation institution ABET. This is considered an "outcome" and it can be found in "section g" from the ABET aptitudes, [2]. This outcome evaluation is based on the studies of [3], [4], [5].

As this aptitude is required in future engineers, it needs to be evaluated during the engineering degree. The evaluation of this skill should be as objective as possible. Normally, it is not acceptable that the evaluation of this skill consists on a simple score based on a general observation of the evaluator, and then, the evaluator states if this student is a good or bad communicator. For this reason the evaluation is divided among several small skills that are easily appreciated.

The following different skills are the starting point for developing a methodology for its evaluation and they include:

- Remembering information previously obtained.
- Understanding the meaning of the information.
- Applying the knowledge to actual situations.
- Threshing ideas and concepts in smaller and simplified parts and then relates these concepts.
- Regrouping ideas in a new whole.
- Making value judgments based on internal evidences.
- Having the sensitivity or will to accept critics, and he responding actively to conflicts.

These concepts are related to more specific attitudes that can be scored by the evaluator.

In the Nuclear Power Plants course, it was thought adequate to implement this evaluation given that the students perform an oral presentation and a written redaction. In this paper the specific methods used to evaluate these skills are presented.

2. Efficient Communication skill evaluation

During the course there are two opportunities to evaluate the communication skills of the students. The students have to make a presentation during the course and they also have to present a written work. During the presentations the oral skill is evaluated, and the written work is evaluated to obtain the score in written communication.

Prior to this evaluation class, there is a specific class in where the evaluation criteria is exposed to the students. The teacher explains what is important during an oral presentation, what are the key aspects to take into account and a few tips of a person that has been giving speeches several years.

Additionally, in this class, three students from the drama club of the school were invited to share their thoughts and advices to the students related to what is important when they are on stage. It is thought that this kind of advices will last longer in student's memory.

2.1 Oral Communication skill evaluation

The evaluation of the oral communication skill is made during the presentations that the students have to make during the course. During the presentation they are asked to speech as if they are selling a project to a company, so a formal style is required. During the presentation they are also asked to make audiovisual content with any slideshow software. This presentation involves technical content that about a new type of nuclear power plant that has to be studied by the student.

A score from 0 to 5 is given to several concepts shown below. These concepts are known by the students, so they know what is going to be evaluated, and they therefore know what skills they need to improve.

The evaluation is made during the presentation by an external evaluator, this means that during this technical presentation, there will be a technical content evaluator and a oral communication evaluator. The student score will be obtained as a function of the scores of the evaluated fields. (This means that if during a presentation there were no questions, the student still can obtain the maximum score).

The evaluators guide of each of these aptitudes is presented below (Table 1):

Maintains the visual contact with the public	It will be scored positively if the speaker has the capability of maintaining the visual contact with the whole audience, changing the focus from near to far and not keeping with the eyesight still in the projection.
Modules the voice during the presentation	It will be scored positively if the speaker modules the voice using changes of tone when referring key concepts. If the speaker maintains a monotonous tone it will be scored negatively.
Body language is adequate	It will be scored positively if the speaker uses the body as an attention catcher for the public, using approximations and gestures to the public as dictates the presentation rhythm. It will be scored negatively if the body language reveals anxiety, stress or insecurity like for example the inability of standing still or crossing arms.
The style of the presentation is coherent with the audience	It will be scored positively if the student adjusts his/her language and body language depending on the audience he

	or she is theoretically presenting to.
The velocity of the speech is adequate	It will be scored positively if the number of words per minute is between 85 and 120.
The presentation is organized	It will be scored positively if the presentation has an introduction, a development of the idea or concept, and some conclusions well differentiated from the rest of the presentation. It will be scored positively if the presentation has the number of the slideshow.
The material of the presentation is coherent with the audience	It will be scored positively if the use of visual resources and animations is proper and coherent with the audience they are presenting to. It will be scored negatively if the presentation has an excessive amount of text on it.
The information repetition is managed correctly	It will be scored positively if the speaker makes pauses or repetitions on the most important or complex concepts. It will be scored negatively if the speaker spends an excessive amount of time in less important concepts.
The speech does not seem to be just a recall from memory	It will be scored positively if the speaker has the ability of being relaxed during the presentation. It will be scored negatively if the speaker seems to make the lecture totally recalling from memory with no capability of change or flexibility
He/she makes an attention catcher strategy	It will be scored positively if the speaker performs an act or strategy with the goal of catching the audience attention in certain moment of the presentation, and if this act is previously thought.
Listens politely when he/she is asked during a question	It will be scored positively that during the questions turn, the speaker does not interrupt the questioner under any concept and that he/she listens standing still. It will be scored negatively if the speaker has an inadequate body language, crossing his/her arms or ignoring the persons who asks.
Answers the questions until those are fully answered	It will be positively scored if the speaker has the ability of knowing when the person who has made the question has his doubt satisfied, and on the contrary keep explaining the answer until it is fully understood.
Answers the question with confidence	It will be scored positively if the speaker is confident with himself during the questions turn, and that he/she shows confidence even when the answer is "I'm afraid I don't know that". It would be scored negatively if the speaker makes

	hesitations.
Confidence in oral communication as a communication method	This will be the less objective score. It will be scored positively if the speaker has great oral communication skills overall.

Table 1. Evaluation Guide for Oral communication skills

2.2 Written communication skills.

The evaluation of the communication skills is made through a written work all students have to make. This assignment involves technical content that about a new type of nuclear power plant that has to be redacted by the student. The assignment should have an introduction, a central part, and the conclusions, that should fit in a single sheet.

A score from 0 to 5 is given to several concepts shown above. These concepts are known by the students, so they know what is going to be evaluated, and they therefore know what skills they need to improve.

The evaluators guide of each of these aptitudes is presented below (Table 2):

Standard locution formats	It will be scored positively the use of standard locutions used in the technical field of the content.
Paraphrases	It will be scored positively the ability of the student of not repeating the same words and structures in the writing
Resuming content	It will be scored positively if the writer can adequately synthesize external and his own content.
Spelling mistakes	It will be scored positively if the writing does not have any spelling mistake.
The information is structured	It will be scored positively if the writing is has clarity and an order when differentiating concepts or separated parts. It will be also scored positively if there is a smooth transition between parts.
Writing style is coherent with the audience	It will be scored positively if the style is adequate for the audience it is supposed to be.
Acronyms and conventions	It will be scored positively if the student uses specific language, expressions or acronyms from the discipline the student is writing about.
Adequate graphics and images	It will be scored positively if the images and graphics are framed, referenced and understandable.
Writing format	It will be scored positively if the format is maintained during the whole document, as well as the use of bullets, justification

	of the text, letter font, line spacing and margins
Opinions stated obey to logic	It will be scored positively if the opinions or conclusions of the writing have relationship with the main content exposed, in a rational and logic way.
Information sources are traceable	It will be scored positively if all references and sources used are quoted, and those are easy traceable.
Confidence in written communication as a communication method	This will be the less objective score. It will be scored positively if the writer has great writing communication skills overall

Table 2. Evaluation Guide for writing skills

3. Conclusions

In the nuclear power plants course a development of efficient communication skills has been implanted. An evaluation method based on the EC-2000 has been proposed. The students were given the evaluation criteria, and a specific master-class explaining what are the key concepts they should master when facing a real presentation or a written report.

The evaluation method tries to be as objective as possible, given that this is a engineering school, and that subjectivity should be reduced to minimum. Therefore, many small concepts responsible for a good communication are chosen to be evaluated, not only because they are easy to score, but also because they are quickly understood by the students.

The students seem enthusiastic about this initiative; communication skills could only be learned and developed in optional courses during the engineering study program, and this is an opportunity they were willing to take.

After the course it was noted a correlation between the technical scores of the presentation and the communication scores. This may imply that a good student learns and understand oral and written communication techniques just as he or she can understand technical information.

This initiative will be continued in the following courses, and the evaluation method has been liberated to the whole Technical University of Madrid so it can be applied in any course.

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LAWRENCE LIVERMORE NATIONAL LABORATORY'S NUCLEAR CRITICALITY AND REACTOR PHYSICS EXPERIMENTAL TRAINING ASSEMBLIES AND ACTIVITIES

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ABSTRACT

Lawrence Livermore National Laboratory's (LLNL) Nuclear Criticality Safety Division has extensive experience deploying hands-on training to experimentally demonstrate criticality, neutron multiplication, and reactor physics concepts. LLNL has taught the U.S. Department of Energy's Nuclear Criticality Safety Engineer Hands-on Training Course for ten years using the Training Assembly for Criticality Safety (TACS). The TACS is a subcritical assembly composed of eight nesting hemishells of 93% enriched uranium that fit together to form a 23 kg sphere with a central cavity. Using the "Approach to Critical" experimental method, the effects of mass, moderation, reflection, separation distance, operator hands, and neutron poisons are demonstrated to the students through hands-on laboratory work.

Following de-inventory of high security materials from LLNL, the TACS was transferred to a secure facility in Nevada and a new subcritical assembly for training and detector development purposes was designed and built at the Livermore site. The new assembly, the Inherently Safe Subcritical Assembly (ISSA), uses up to nine modified surplus MTR type fuel arranged in a square lattice in a water tank. Each assembly contains nineteen curved plates with 232 grams of ^{235}U of highly enriched U_3O_8 dispersed in a matrix of aluminum and fully clad in aluminum. Current hands-on experiments with ISSA include approach to critical by mass (number of assemblies) and moderator height, demonstration of detector placement effects, effect of core shape on leakage, and measurement of buckling and extrapolation length.

In the near future LLNL, in partnership with the Institut de Radioprotection et de Sûreté Nucléaire at Fontenay-aux-Roses, France, is planning to develop a fundamental physics subcritical multiplicity benchmark for ISSA at three or more levels of subcritical multiplication for publication in the International Handbook of Evaluated Criticality Safety Benchmark Experiments.

1. Introduction

This paper will describe two unique training assemblies at LLNL, the TACS and ISSA, used to demonstrate concepts of criticality, neutron multiplication, and reactor physics. The TACS was used extensively as a training aid for fissile material handlers, criticality safety engineers, managers, and regulators at LLNL since 1979. De-inventory of high security materials at LLNL was completed in September 2012, which required transfer of the TACS to the Nevada National Security Site (NNSS), where it is still used for national hands-on criticality safety training. Consequently, the Nuclear Criticality Safety Division at LLNL decided to build a new subcritical assembly for training and detector development purposes that could be conveniently utilized by laboratory researchers, visiting scientists and students in a low security environment at the main laboratory site.

2. Training Assembly for Criticality Safety

During the 1950’s and 1960’s, LLNL did many critical and subcritical experiments to provide basic validation data for its computer codes. The Nimbus program used a set of nesting highly enriched uranium (HEU) hemishells at 93.15% enrichment [1]. In 1979, a training assembly was created for use with eight of the Nimbus shells to aid in on-site LLNL Fissile Material Handler (FMH) training [2]. The eight Nimbus shells fit together to form a 23 kg sphere with a central cavity. The outer radius of the HEU is 7.925 cm. Lucite (acrylic, $C_5O_2H_8$) moderators of varying thicknesses can be placed inside the cavity and hemispherical Lucite reflectors of varying thicknesses can be fit on the outside of the assembly. The TACS is assembled on an assembly table that can be raised and lowered by means of a hand crank (Figure 2).

Figure 1: Eight HEU shells (left) and four nested shells that form lower half of the assembly (right).

Fig. 2. The Training Assembly for Criticality Safety, shown with a 3” gap separating the hemispherical halves.

2.1. TACS Experimental Method

The TACS is a subcritical assembly that achieves a maximum multiplication of approximately 10, corresponding to an effective multiplication factor (k_{eff}) of about 0.90. The assembly is driven by a neutron source to quickly obtain meaningful count rate data with ^{3}He neutron detectors.

Laboratory experiments [3] follow the "Approach to Critical" experimental method. For Approach to Critical by fissile mass, for example, the students begin by building a non-multiplying assembly using depleted uranium (DU) shells reflected and moderated by Lucite. A count rate measurement is taken, which determines the baseline of unmultiplied source neutrons emitted from the assembly. One DU shell is replaced with a similar amount of HEU and another count rate is taken. By dividing this second multiplied count rate by the baseline unmultiplied source count rate, corrected for background neutron counts, an experimentally observed multiplication, M_{obs}, is determined. By plotting $1/M_{obs}$ versus the fissile mass and linearly extrapolating to the point when $1/M_{obs}$ reaches zero, an estimate of the fissile mass needed to achieve criticality can be made. An example of an Approach to Critical, or 1/M, curve, with data from the TACS, is shown in Figure 3.

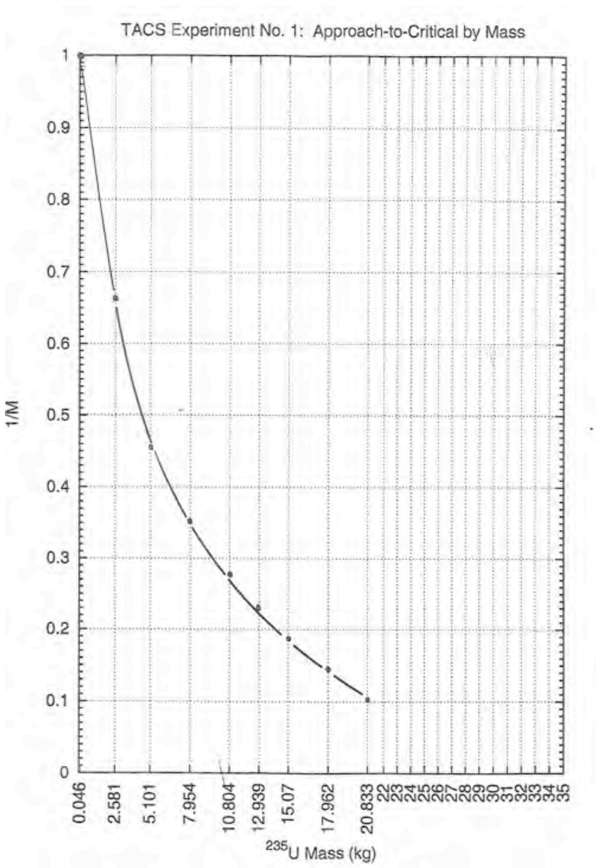

Fig. 3. Approach to Critical by Fissile Mass Curve. Critical was estimated to be 28 kg of ^{235}U mass by extrapolation to the X-intercept.

The TACS assembly was designed to be highly versatile and demonstrate many of the parameters that affect nuclear criticality. Six experiments are completed during the laboratory: Approach to Critical by Fissile Mass, Approach to Critical by Lucite Moderation, Approach to Critical by Lucite Reflection, Approach to Critical by Separation Distance, Effect of Reflection by Operator Hands, and the Effect of Neutron Poisons.

2.2. TACS Utilization

The TACS was originally designed to train LLNL FMHs in an experimental basis for the parameters that affect criticality. It was used for this purpose from 1979 until the late 1980s.

In 2006, the US Department of Energy's Nuclear Criticality Safety Program Manager requested that LLNL begin offering a hands-on criticality safety training course to Nuclear Criticality Safety Engineers during the relocation of the Los Alamos National Laboratory (LANL) Critical Experiments Facility at TA-18 to the NNSS. In 2012 the TACS was also relocated from LLNL to a secure facility at the NNSS. LLNL continues to provide the training in conjunction with LANL at the NNSS.

Based on the many years of data accumulated during the conduct of the class, a paper was written that gave an experimental basis for quantifying the effects of operator hands on a fast metal system [4].

3. Inherently Safe Subcritical Assembly

3.1 Design Considerations for ISSA

Inherent safety, accessibility, low cost, and simplicity were major considerations identified during conceptual design. The fuel design concept was to use encapsulated fuel to avoid need for establishing a contamination area. Furthermore, the intrinsic radiation present in the fuel and external neutron sources should be strong enough to enable meaningful multiplication measurements within reasonable count times while weak enough to avoid establishing a radiation area and requiring associated controls. The amount of fuel should be limited to preclude any credible risk of a criticality accident. These inherent safety features identified during conceptual design inspired the name Inherently Safe Subcritical Assembly (ISSA). From the outset, the LLNL design goal was to enable a “hands on” student experience rather than student observations of a demonstration by a qualified or licensed operator.

Most importantly, the fuel “attractiveness level” should be as low as possible to minimize security requirements and enable easy access to persons without security clearances including university students. To minimize costs, surplus materials were used wherever possible.

Simplicity of operations led to consideration of highly enriched uranium fuel in order to minimize the size of the assembly. Furthermore, it was recognized that bundling the fuel elements into subassemblies could minimize the number of fuel handling operations enabling rapid fueling and defueling operations. A literature review led to a design concept of using surplus encapsulated un-irradiated highly-enriched uranium Materials Test Reactor (MTR) type fuel assemblies supported in a simple lattice structure within a cylindrical tank for moderation by water as illustrated in Figure 4, which shows a lattice of SPERT-D fuel elements used in critical experiments at Oak Ridge National Laboratory in 1964-1965 [5].

Figure 4. Design Concept

Two other conceptual design considerations included the desirability of installing a core tank much taller than the active fuel length to enable measurements of higher harmonic flux effects and to elevate the tank above the floor to enable access to the tank bottom for placement of neutron sources away from student handlers and to enable source jerk measurements. An elevated tank is a design feature we noted in the DELPHI [6] subcritical assembly and the Jordan Subcritical Assembly [7].

3.2. ISSA Final Design

The final design realized uses up to nine modified surplus MTR type fuel assemblies from the Omega West Reactor (OWR) [8] manufactured by the Naval Nuclear Fuel Division of Babcock & Wilcox (B&W) in Lynchburg, Tennessee, USA. Each assembly contains either 220 or 232 grams of ^{235}U of highly enriched uranium within nineteen curved plates containing either 11.5 or 12.2 grams of ^{235}U in U_3O_8 dispersed in a matrix of aluminum and fully clad in pure aluminum. These assemblies were significantly reduced in size by LLNL to an approximate length and weight of about two feet and twelve pounds for ease of handling. LLNL modified the original assemblies by removing the aluminum end pieces (i.e., the “nozzles” used in the Omega West Reactor for fuel positioning and handling) and fabricated new aluminum fixtures for the top and bottom of the fuel elements to aid in their placement into the lattice array. Photographs of an OWR fuel assembly modified by LLNL are provided in Figure 5.

With 9 fuel assemblies arranged in a water tank, the subcritical assembly has a peak multiplication of approximately 20.

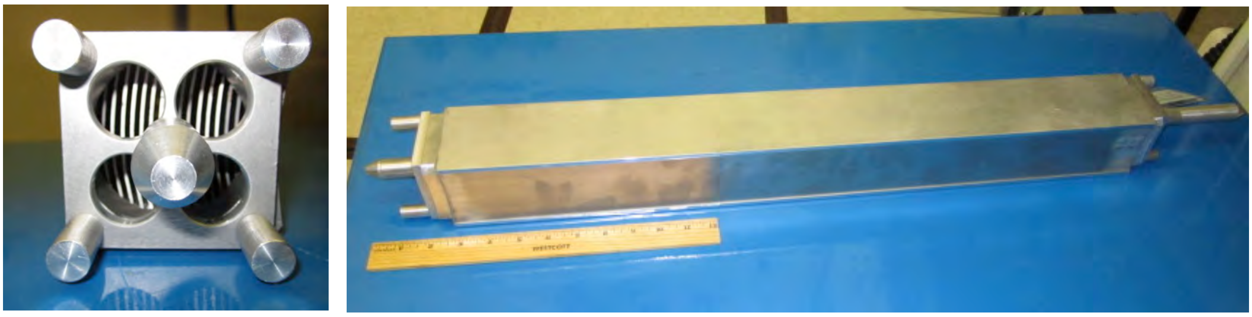

Figure 5. LLNL Modified OWR Fuel Assembly

The design layout of the ISSA is shown in Figure 6. The core tank, shown as the dark gray cylinder in the center of the platform, is a surplus tank used previously for chemical etching. The water dump tank, shown as the white tank to the right of the platform, was previously used on a truck bed for cleaning up large wastewater spills. The overhead crane was excess equipment from another facility. The stairs, railings, platforms and their supports were taken from surplus office trailers.

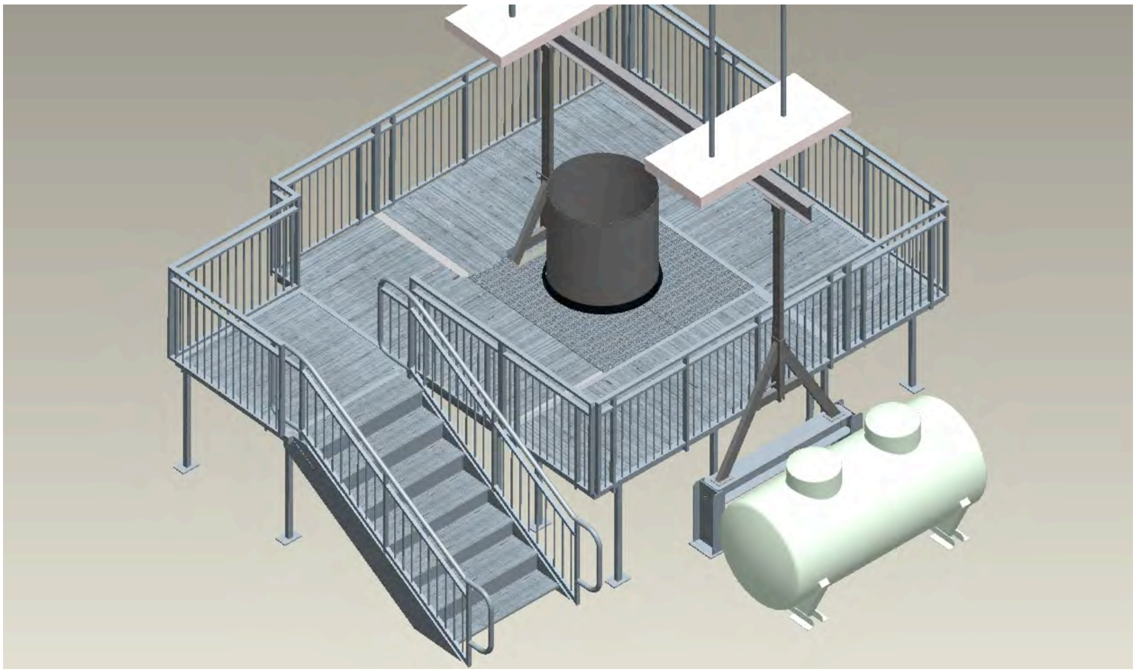

Figure 6. Design Layout of the ISSA

Other repurposed items were ^{3}He detectors taken from health physics survey instruments and eight large ^{3}He detectors recovered from an obsolete multiplicity drum counter. Several 110-gallon DOT-6M/2R obsolete shipping containers were also obtained for fuel assembly storage. Major parts fabricated by LLNL include the tank support stands and seismic restraints, detector tube wells and their supports and the aluminum core lattice. LLNL also fabricated all aluminum "mock fuel" assemblies to original B&W manufacturing drawings. These assemblies are useful in establishing an unmultiplied base count rate for subcritical multiplication measurements. Minor procurements included a water pump and associated piping and controls, drum storage racks and locking drum lids. Eberline model E-600 detectors are used to power and record counts with the small ^{3}He tubes and the large ^{3}He tubes are used with prototype Fission Meters for multiplicity counting. These detectors and ^{252}Cf sources are on loan from other laboratory programs. A photograph of the ISSA "as built" configuration is provided as Figure 7.

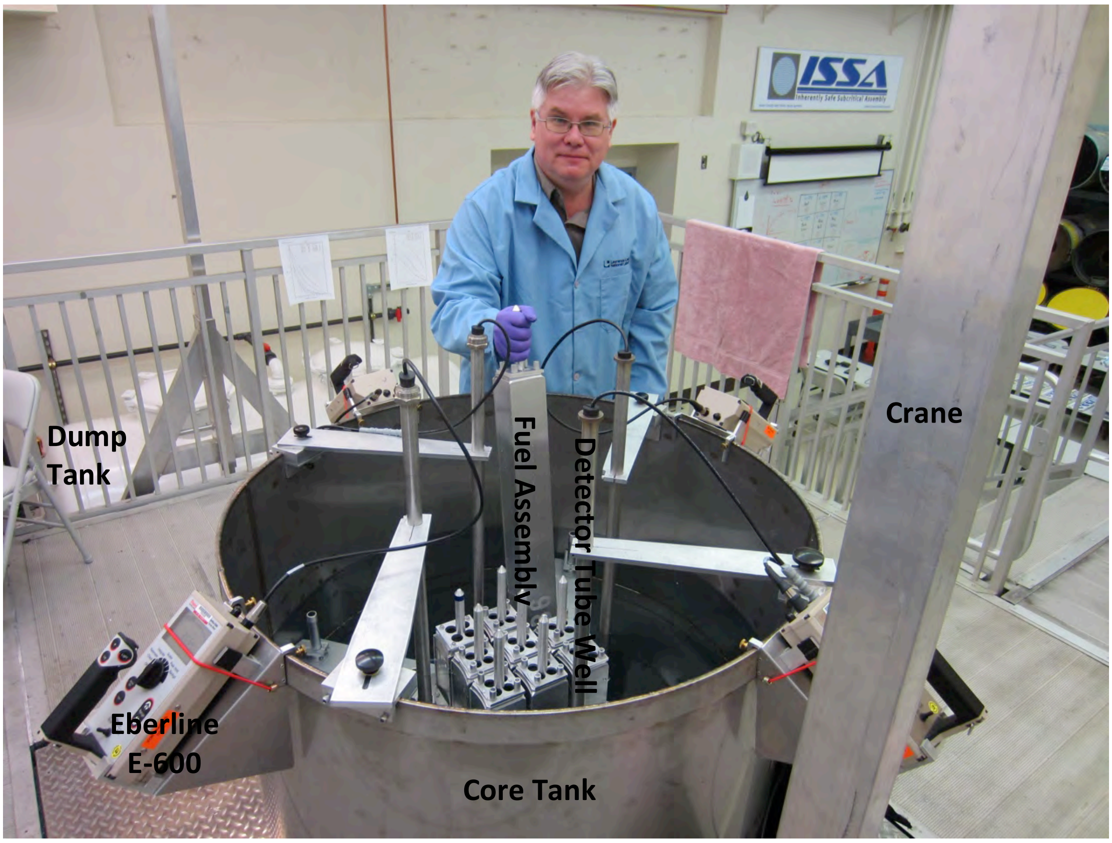

Figure 7. ISSA "As Built" Configuration

3.3 ISSA Utilization

The ISSA was designed as a training aid and as a multiplying assembly for the development of detectors including multiplicity detectors such as prototypes for the LLNL-designed ORTEC Model FM-P3 Fission Meter and next generation detectors. As a training aid for the fundamentals of subcritical reactor physics, the syllabus given in Table 1 was as originally envisioned in 2011-2012. Those subjects of the syllabus actually completed and ready to teach are indicated with a check mark. Use of ISSA as a training aid for safeguards measurements is also under consideration.

ISSA was authorized for use on September 7, 2012 and the first approach-to-critical was completed on September 13, 2012 with typical inverse multiplication curves determined by student measurements as shown in Figure 8. Note that the estimated critical number of ISSA fuel assemblies by extrapolation of inverse multiplication measurements is 11, which is in excellent agreement with safety calculations completed in COG10 [9].

Table I. Syllabus

Lectures	Experiments
Basic physics • Inherent sources of neutrons • External neutron sources (^{252}Cf) • Neutron cross sections ✓ Physics of chain reactions • Diffusion and Fermi age theory ✓ Modified one group diffusion equation ✓ Neutron kinetics equation • Statistics of chain reactions Hand calculations • Six factor formula ✓ Diffusion constants ✓ k-infinity, migration area and buckling ✓ Nucleonics data sheet no. 38 ✓ Alpha, k_{eff}, reactivity • Count distributions and Feynman-Y Computer codes ✓ RHEINGOLD (Diffusion) [8] ✓ ARDRA (S_N) ✓ COG (Monte Carlo)	Source multiplication experiments ✓ 1/M vs. mass (or number of assemblies) ✓ Detector placement effectors ✓ Source effects ✓ 1/M vs. moderator height • 1/M vs. pitch • Effect of over/under/optimum moderation • Effect of isolation by water • Effect of neutron poisons (including flux traps and control rods) • Effect of reflector materials ✓ Effect of core shape on leakage • Temperature reactivity coefficient • Fuel reactivity coefficient • Void reactivity coefficient Dynamic experiments • Source jerk • Pulse die-away ✓ Feynman-Y Spatial methods ✓ Buckling and extrapolation length

In the near future LLNL, in partnership with the Institut de Radioprotection et de Sûreté Nucléaire at Fontenay-aux-Roses, France, is planning to develop a subcritical benchmark for ISSA at three or more levels of subcritical multiplication for publication in the International Handbook of Evaluated Criticality Safety Benchmark Experiments. Measured count distributions at the highest level of multiplication attainable in the current design were completed in 2014 to demonstrate feasibility. Typical list mode data for a count distribution and Feynman-Y fit are shown in Figure 9. Preliminary analysis results indicate a multiplication of about 22.5 corresponding to keff = 1 – 1/M = 0.955 [10].

4. Conclusions

LLNL has a long history of developing and deploying unique hands-on nuclear training assemblies. After de-inventory of the LLNL site and relocation of the TACS to the NNSS, ISSA was developed at low cost as an institutional laboratory asset and is inexpensive to maintain. ISSA is available for “hands on” training and as a multiplying assembly for detector development. Due to inherent safety by design, students and visitors to the laboratory are authorized to handle the fuel, operate the detectors, water pump, etc., and execute all measurements under supervision. The only student prerequisites are General Employee Radiation Training, which is a read and sign instructional booklet that can be completed prior to visiting LLNL, and a pre-job briefing in the ISSA laboratory on the hazards and controls specified in the authorization basis.

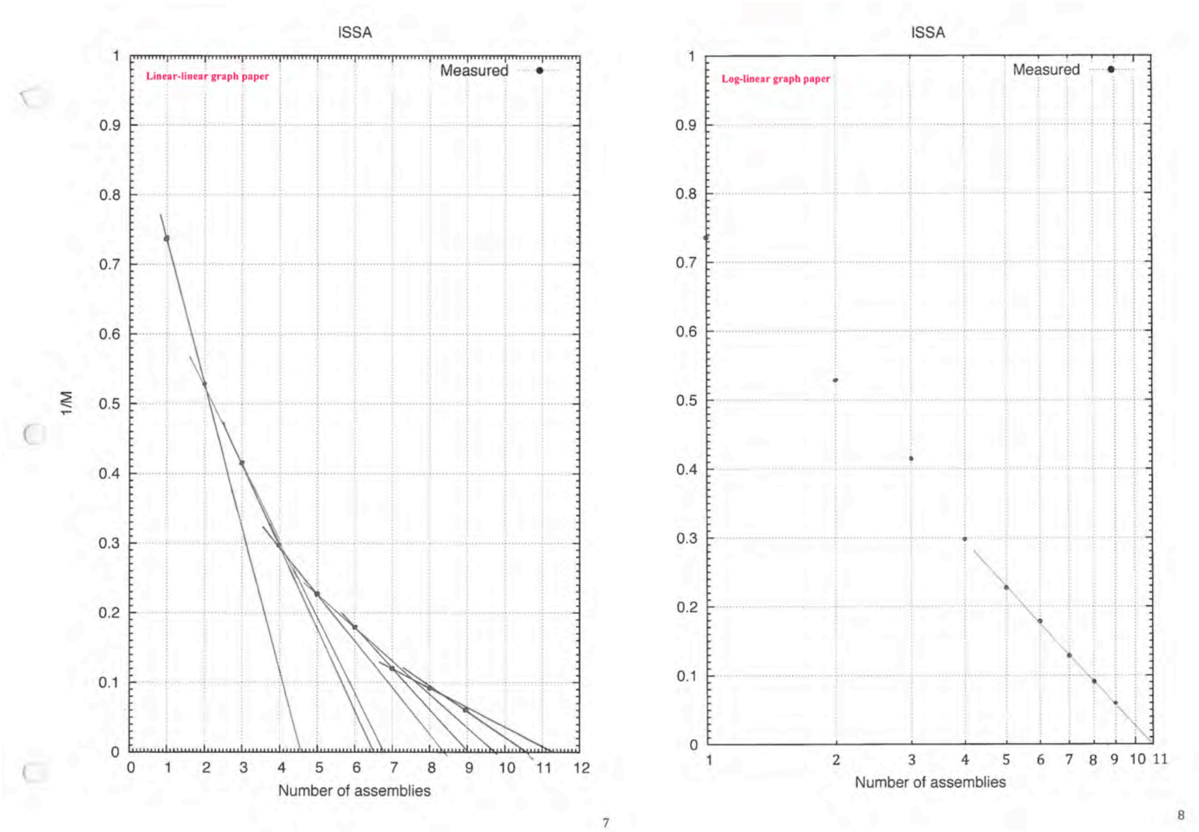

Figure 6. Typical Inverse Multiplication (1/M) Curves

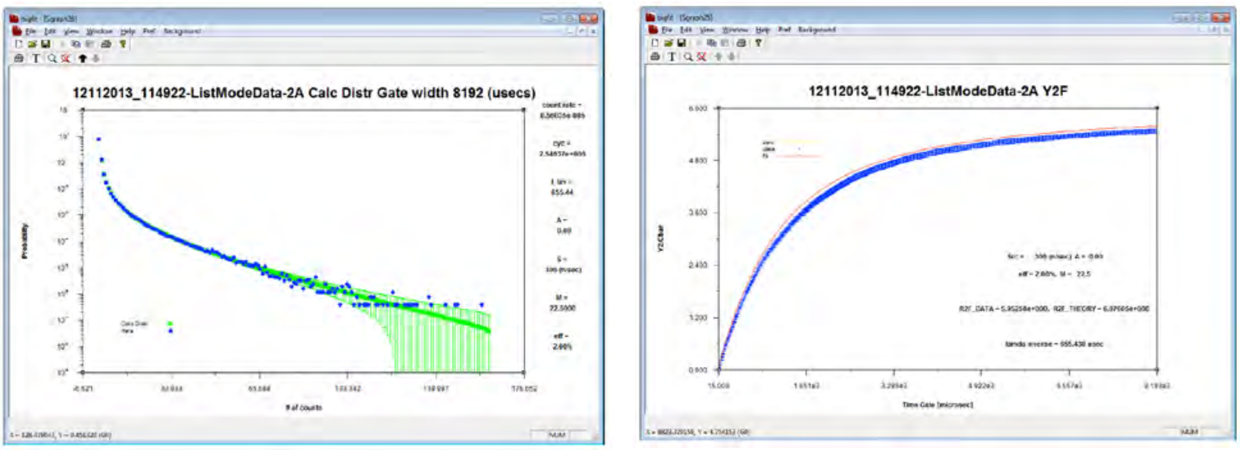

Figure 7. Typical Measured Count Distribution and Feynman-Y Fit at M=22.5

5. Acknowledgments

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ASSESSING THE RETURN ON INVESTMENT (ROI) OF TRAINING IN THE SPANISH NUCLEAR INDUSTRY

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ABSTRACT

Tecnatom has conducted several actions to enhance the quality and standards of training services. One of these actions, based on performance improvement of the plant has been focused in measuring the return on investment (ROI) when conducting training activities.

Learning evaluation models measure the impact of training investment against the results obtained. These tools evaluate learning, performance and economic objectives among others.

Based on the evaluation of training models developed by Donald Kirkpatrick and Jack Phillips, it has been designed a methodology to assess the effectiveness of a training activity carried out in a Spanish NPP. This activity was related to a gap observed during the continuous training of field operators.

The importance of this experience is that it is the first time in which Tecnatom successfully applies a training effectiveness methodology which includes determining ROI in training environments.

The model developed implies the analysis of five levels of evaluation: reaction, learning, changes in behavior, business impact and ROI of training. Therefore, once the data was collected, the following activities were conducted:

- Level 1 (Evaluation of Opinion) analysis of student surveys to determine course quality.
- Level 2 (Learning) data is analyzed before and immediately after training to evaluate the knowledge and skills acquired.
- Level 3 (Application and Implementation) evaluation of the student behavior in their daily work with data taken some time after the training.
- Level 4 (Business Impact), probability of error derived from the training gap is determined using information from the Probabilistic Safety Assessment (PSA), the tasks related to the personnel involved and plant data on the frequency of equipment failure.
- Level 5 (ROI), analysis of the cost of training against economic benefits derived from the reduction of the risk of damage in the equipment.

This work allows Tecnatom to validate the use of this methodology and the possibility of applying it to other training activities. This technique has a high potential, since allows organizations to identify the effectiveness of training from a business and financial point of view.

1. Introduction

SAT methodology is a proven and structured method for efficient qualification focusing on the performance of work, addressing the needs and deficiencies of the personnel and organisations. The results of the training contribute to improving the results of the work and the professional development of people.

This methodology has five stages, these are: analysis, design, development, implementation and evaluation.

The evaluation phase serves for the continuous monitoring, verification, maintenance and improvement of training programme performance.
It focuses on two aspects:

- Determine the effectiveness of the training as regards producing competent workers.
- Compare the contents, structure and processes of the training programme with the industry standards, recommendations and guidelines

The evaluation process identifies performance problems that can be solved by improved training and identifies new or changing training needs. The output of the evaluation phase serves as feedback for the analysis, design, development and implementation phases so the training program can be modified and improved.

Donald Kirkpatrick and Jack Philips developed five levels of evaluation:

- Level 1 (Evaluation of Opinion) analysis of student surveys to determine course quality.
- Level 2 (Learning) data is analyzed before and immediately after training to evaluate the knowledge and skills acquired.
- Level 3 (Application and Implementation) evaluation of the student behavior in their daily work with data taken some time after the training.
- Level 4 (Business Impact), focuses on the business results achieved through training.
- Level 5 (ROI), return on investment.

Tecnatom has designed a methodology based on the evaluation of training models developed by Donald Kirkpatrick and Jack Phillips, it has been designed a methodology to assess the effectiveness of a training activity carried out in a Spanish NPP. This activity was related to a gap observed during the continuous training of field operators

2. Background

In 2014 two field operators made an error while they were putting clearance tags in the switchyard, the action did have no consequences. A shift manager was carrying out an observation of this job, as a result of the observation was identified a performance gap.

The performance gap analysis made to field operators revealed the follow results:

- Failures in the identification and localization equipments in the switchyard.
- They did not know which areas were responsible in the switchyard.

These results were start point the assessing the return on investment (ROI) of training in the Spanish nuclear industry.

3. Project Design

The main objective was to design and develop training for field operators based on the results the performance gap analysis.

The evaluation of learning is concerned with measuring the extent to which desired attitudes, principles, knowledge, facts, techniques and skills that are presented in the training have been learned by the participants.
The measures were made three times:

- The first measure was made before the training and it took data the knowledge and skills field operators already had.
- The second measure was made after the training and it took data the knowledge and skills they have been learned in the training.
- The third measure was made a year after training and it took data the operator field skills.

These data are used to confirm that participant learning has occurred as a result of the training.

The methodology developed to assess the effectiveness of training is based in the four evaluation levels by Donald Kirkpatrick and the fifth evaluation level by Jack Philips.

Bellow, the data obtain for each evaluation level.

3.1 Level 1: Reaction (Evaluation of Opinion)

Reaction data reveals what the participants thinks of the training and the trainers.

At Level 1, the training was evaluated by surveys and the data obtained were the following:

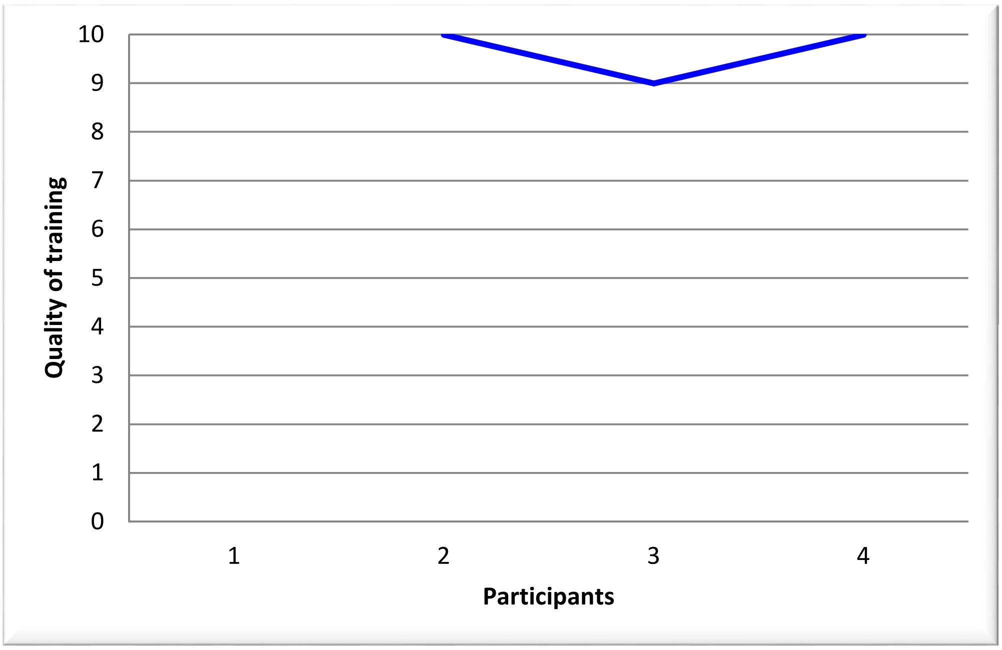

Fig 1. Participants´reaction

Feedback was very positive. Training participants rated the course 9.6 out of 10 in an overall assessment. Participants enjoyed the training and indicated that it was relevant to their jobs. The quality of training was considered like satisfactory for participants.

3.2 Level 2: Learning

At Level 2, measurements focus on what the participants learned during the training. This evaluation is helpful in determining whether participants have absorbed new knowledge and skills and know how to use them as a result of the training.

This evaluation occurred before and after of training (pre- and post- training). The data were collected by testing. There were two kind of tests:

- Knowledge test, was a written test.
- Skill test, was developed a test based in the identification and localization of equipments in the switchyard

The data obtained were the following:

- Knowledge test:

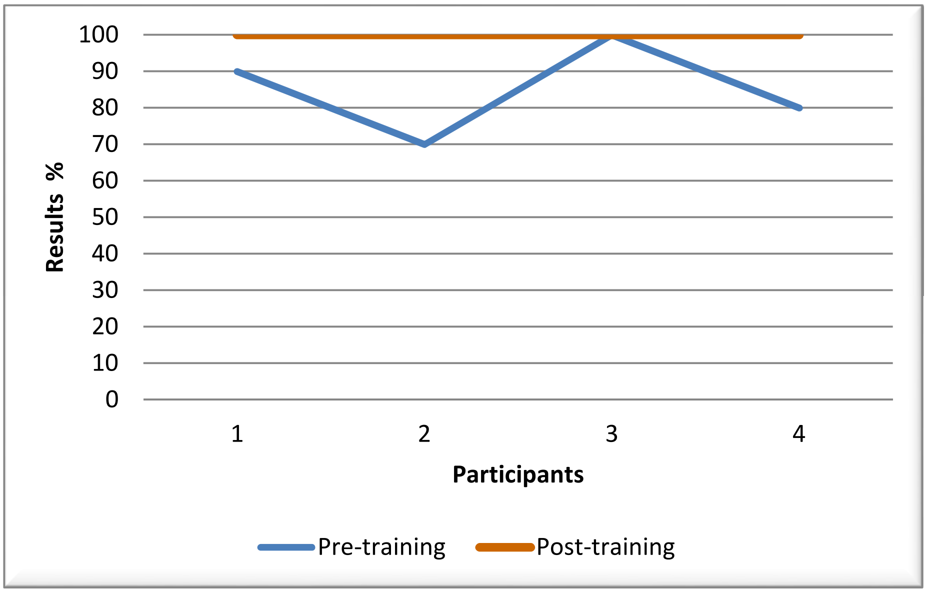

Fig 2. Pre- and Post- Knowledge test

- Skill test, was took as a measure skill the time t. The time participants spent looking the equipments in the switchyard.

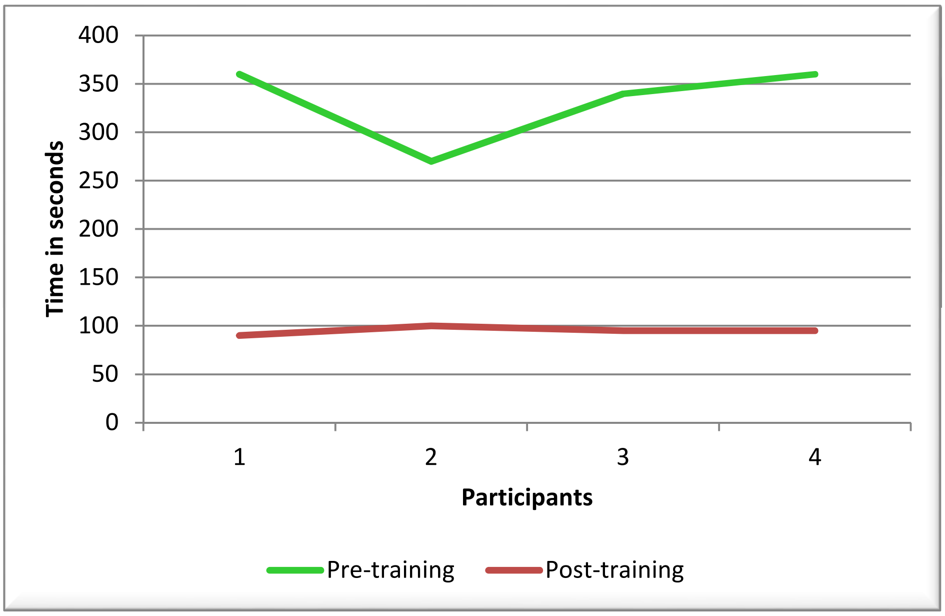

Fig 3. Pre- and Post- training skill test

Participants learned new knowledge related with the equipments in the switchyard. An observation of skill practices verified that the team members acquired adequate skills.

Both of graphics show the training results obtained before and after the implementation.

At Fig 2 observed knowledge improvement after the implementation. The test results after are better than before the training.

At Fig 3 observed skill improvement after the training. Was used time, t, like a measure the participants´ skill. The participants reduced the identification and localization time the equipments in the switchyard.

Training has contributed to improve knowledge and skill of participants.

3.3 Level 3: Application and Implementation

The Level 3 measures behavioural change on the job. It is measured after the training has been implemented in the work setting.

This evaluation was made a year after the training (in 2015) and was the same than skills evaluation in Level 2.

The data obtained were the following:

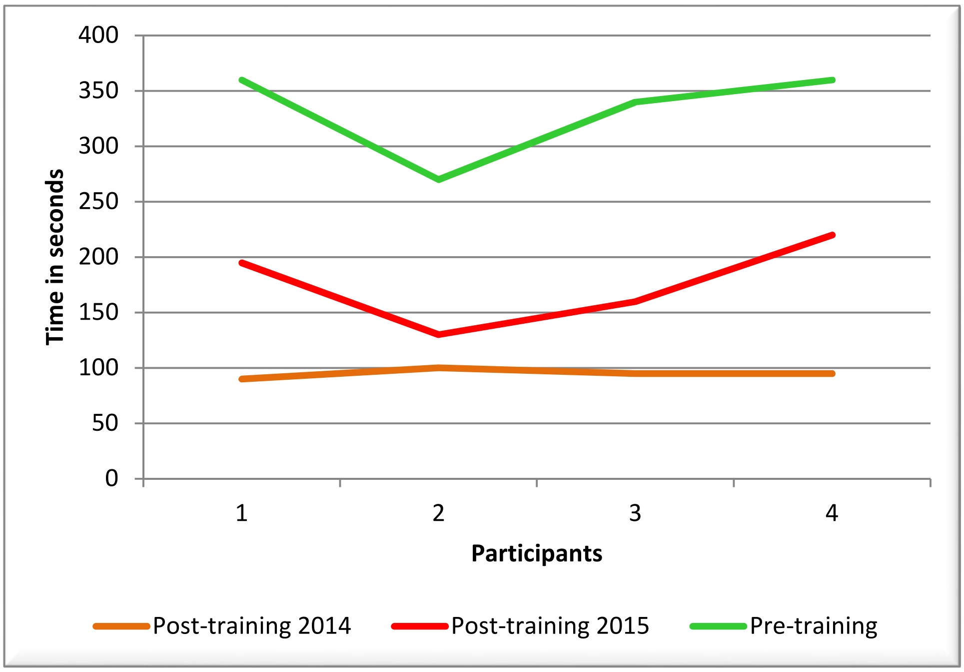

Fig 4. Implementation in work

At Fig 4 is compared the skills of participants before, during and a year after the training. Is improved skill of participant a year after training. The participants applied the skills acquired during the training on the job.

3.4 Level 4: Business impact

At Level 4, measurement focuses on the actual business results achieved as a consequence of applying the knowledge and skills from the training. The evaluation focus is on the impact of the training process on specific organizational outcomes.

The training was designed and development in base a performance gap. This performance gap could not be related with a plant indicator so an indicator was created based on this performance gap.

The indicator was: "Reduction of the risk of damage in the equipment from bad colocation clearance tags in the switchyard".

Was measured the indicator reduction before and after the training. The measurement the indicator was determined using information from the Probabilistic Safety Assessment (PSA), SAT and data plant. Were used:

- PSA data: probability of error derived from bad colocation clearance tags.
- SAT data: (Systematic Approach to Training): the tasks related in the switchyard to the field operators.
- Plant data: the scram frequency based on equipments failures in the switchyard.

The result obtained was a decrease the 63.33% of the risk of damage in the equipment from bad colocation clearance tags in the switchyard after the training.

3.5 Level 5: ROI (Return on Investment)

At Level 5, the measurement compares the monetary value of the benefits resulting from the training with the actual costs of the training.

Were analysed the cost of training against economic benefits derived from the reduction of the risk of damage in the equipment from cad colocation clearance tags in the switchyard (indicator).

Calculations are as follows:

Training costs for four participants = 12.500€

First-Year benefits from reduction of the risk of damage in the equipment = 168.660€

We have an estimate as to why the measures improved and the extent to which the training influenced the improvements. The data shows a definite improvement linked to the training.

4. Conclusions

Is the first time in which Tecnatom successfully applies a training effectiveness methodology which includes determining ROI in training environments.

This work allows to validate the use of this methodology and the possibility of applying it to other training activities. This technique has a high potential, since allows organizations to identify the effectiveness of training from a business and financial point of view.

‘Talking nuclear’ in schools and to civil society

DEVELOPMENT AND ACTIVITIES OF EDUCATION PROGRAMME, "TOWARD A SAFE AND DISASTER-RESISTANT SOCIETY"

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ABSTRACT

The development of human resources is key issue for safety management of worldwide nuclear safety environment. Recently, including the severe accident of the Fukushima nuclear power plants, we faced several accidents continually in large industrial facilities in Japan. After these accidents, most Japanese people feel anxiety about both science and technology. We need to rebuild public trust in nuclear safety. Okayama University is one of the leading universities in Japan. Our important role is to challenge the keen social issue and to supply well-educated professionals and technicians continuously. In this paper our activities and challenges on post-graduate studies will be discussed. Since 2008, we have run the project "Engineering Research and Education on Safety and Security under Low-level Radiation Environment". Master and Doctoral education course program on this topic was already established. In January 2014, Okayama University established "Center for Safe and Disaster-Resistant Society" due to enhance and to extend this program that can cover more widely topics. From April 2015, new special program course for graduate school "Toward a Safe and Disaster-Resistant Society" is started. An accident of nuclear plant causes profound effects on the broad region. We need effective leadership when the nuclear plant will be controlled under non steady conditions. When we will correspond to a crisis, a quick decision is required. In addition we should consider how to recover from damage of accident. The information including risk must be shared by all stakeholders. Nowadays when values are becoming diversified we should be recognizing a variety of different types of safety. Thus, safety education becomes more important for our society. We aim to cultivate a safety culture in each engineer and stakeholders through safety education program for our society.

1. Introduction

A safety culture concerns the comprehensive attitudes and characteristics of both individuals and organizations. [1] Though, everybody may have a different sense of values, which ultimately lowers social awareness and creates difficulties in cooperative relationship. Therefore, to build a safety culture in our society, safety education is especially important. Okayama University is one of the leading universities in Japan, as a public institution of higher learning, we can contribute to this advancement by providing a positive environment through research and the passing wisdom to future generations. We have run an education and research project "Engineering Research and Education on Safety and Security under Low-level Radiation Environment" related to nuclear engineering and radiation health problems since October 2008. It has been made much effort to establish a graduate program in this field. In addition, we have keenly joined an engineering project for closing a uranium mine, which has been managed by the Ningyo-toge Environmental Engineering Center of Japan Atomic Energy Agency (JAEA), and these experiences strictly help to develop our research and education programme.[2] After the serious accident of Fukushima in 2011 was originated in earthquake and tsunami, we have many problem to solve for future generations. Especially the radioactive waste management is the keen problem. The cleanup work will last more than 30 years, and the lack of experienced engineers in the field of nuclear waste management becomes obviously. The new environment after the Great Eastern Japan Earthquake and Tsunami should be taken into consideration for our project. Okayama University established the Center for Safe and Disaster-Resistant Society in 2014 due to enhance and to extend educational programme that can cover mitigation of natural disasters and human behavior when committing a severe natural disaster.

2. Over view of Center for Safe and Disaster-Resistant Society

2.1 Center for Safe and Disaster-Resistant Society

The Aims of Center for Safe and Disaster-Resistant Society (hereafter CSDRS), are to conduct research and to build education programme of Master and Doctoral Courses as to take over whole academic results which were from preceding project. In Japan many industrial complex are located near seashore, and it is the most important issue to make research on safety and disaster-resistant society and educate its results at graduate school to produce well-educated engineers. The CSDRS is supported by Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan. The center is open for all faculties of Okayama University, and students from 3 graduate schools can join graduate courses. And also the center prepares the professional education courses for working people. We have arranged some Public Lectures about recently safety topics for all stakeholders. Figure 1 shows Public Lecture “On the Influence of Radiation to Human Health”, and “Industrial Safety Seminar in Okayama”.

Fig. 1 “On the Influence of Radiation to Human Health”, and “Industrial Safety Seminar in Okayama”

2.2 Research Activities of CSDRS

Including Fukushima NPP accident, serious accidents have been continually occurring in large industrial facilities recently in Japan. Our research topics have been extensive covering wide range fields, natural disasters and human behavior and decision making from a broadly perspective. Therefore, CSDRS is on a very firm foundation to extend its influence further through providing continuing professional development courses for industry, widening its public engagement activities and making collaborative arrangement with similar centers internationally. The following shows our main research topics,

・Development of Safety Assessment System for Chemical Plants
・Hazard Identification and Safety Design based on Dynamic Simulation
・Safety Education and Training System using VR/AR
・Advanced Operation Support and Safety Management System
・Evaluation for adaptability of computational methods for elucidation of transportation mechanism of nuclides
・Study on mechanism of radon transportation
・Fundamental study on engineering barrier for radioactive waste
・Study on the Health Effects and Medical Applications by Low Dose Radiation
・Numerical study on the elimination of radioactive cesium chloride from burned materials
・Study on Radioactive Waste Disposal Technology
・Study on Fukushima Environmental Dynamics

Published papers, commentaries books by CSDRS members of this center are summarized in Table 1.

Research Papers	Books	General Remarks and Commentary
126	6	7

Tab. 1 Research papers, commentary and books in past 5 years.

3. Education Programme, “Toward a Safe and Disaster-Resistant Society”

3.1 Outline and Purpose

Special programme course“Toward a Safe and Disaster-Resistant Society” was started for graduate school since 2015. New syllabuses were prepared for students. This education programme is organized as special course for graduate students that provides systematical and comprehensive programme for radioactive waste treatment, disposal, and safe and disaster-resistant society. The purpose of this course is to teach advanced scientific and technical expertise to meet the various safety needs of our society.

3.2 Prerequisite (requirement) for students and Registration Method

Students who intend to take this course must belong to Graduate School of Natural Science and Technology or Graduate School of Environmental and Life Science or Graduate School of Health Sciences. Students who intend to take this course must submit an application form for this course to Okayama University administrative office. Certificate of the course is conferred to students who have completed this course and met the completion requirements.
Completion requirements of this course as follows.
Complete the Master’s course which the students belong to and acquire the number of credits described in an appended table.
A) Completion requirements for the Master's course shall be to acquire 10 credits or more in total, which comprise of 6 credits or more (4 credits from compulsory subjects and 2 credits from elective subjects) and 4 credits or more from special subjects.
B) Completion requirements for the Doctor's course shall be to acquire 6 credits or more from elective subjects, which are specified by one’s academic supervisor.
Certificate of the course completion is conferred on students who have completed this course and met the above requirements.

3.3 Education Programme

We developed Class Subjects for “Toward a Safe and Disaster-Resistant Society” including Master’s and Doctoral courses shown in Figure 2.

A) The Master's course Class Subjects	
Nuclear engineering I Basic course	Radioactive Waste Management I
Human activities and the environment – toward a low-carbon society	Radioactive Waste Management II
Nuclear engineering II Basic course	Environmental Numerical Analysis
Risk Communication for Public Acceptance	Radiological Health Science
Internship in Safe and Disaster-Resistant Society	Radiation Safety Management
Risk analysis Plant Safety Design	Radiobiology Radiation Metrology
Human Resources Risk Management	Study on Radiation and Human
Organizational Risk Management Safety Management	Radiation Protection Study

B) The Doctor's course Class Subjects
Topics in Radiation Safe and Medical Application Study
Topics in Radiation Safe Study
Topics in Radiological Life and Health Science
Topics in Applied Therapeutic Radiology
Topics in Radiation Metrology & Application Study
Safety Management for Nuclear Facility
Resilience Engineering
Evaluation of Geo-environment
Radioactive Waste Management : Theory and Practice

Fig.2 Class Subjects for Special Course for Graduate School

We intend to reflect new knowledge and technology obtained through wide-range researches these subjects. In 2015 the center have 18 students this new program. Between 2008 and 2015 we have 85 enrolled master course students and 15 enrolled doctoral course students, including previous project education course students(from 2008 to 2014). Figure 3 shows employment companies of our graduates. Our students have a job in the various companies not always nuclear industries. Many graduates who are working diverse fields lead to promote the understanding of the nuclear use. The center can make effective connections of graduates that improve safe society to help each other.

Doctoral Course, Okayama University	SANKI ENGINEERING CO., LTD.
Hyogo Ion Beam Medical Center	DENSO CORPORATION
Shigei Hospital	KOBE STEEL, LTD.
KARIYA TOYOTA GENERAL HOSPITAL	NTN Corporation
Beru Rand General Hospital	DAICEL CORPORATION
Advanced Science Research Center, Okayama University	WEST JAPAN RAILWAY TECHSIA Co., Ltd.
NEXCO CENTRAL	FUJITSU TEN LIMITED
JAEA (Japan Atomic Energy Agency)	Hitachi Zosen Corporation
SUMITOMO BAKELITE CO., LTD.	DAIKIN INDUSTRIES, Ltd.
OMRON Corporation	Daio Paper Corporation
Nabtesco Corporation	Nomura Research Institute, Ltd.
THE CHUGOKU ELECTRIC POWER CO.,INC.	JFE Systems, Inc.
Fuji Xerox Co., Ltd.	NTT COMWARE Corporation
GLORY LTD.	Ehime Prefectural Office
NAKASHIMA PROPELLER Co.Ltd.	OSAKA GAS CO., LTD.
DOWA HOLDINGS Co., Ltd.	etc.

Fig. 3 The employment companies of our graduates

This special education programme is set as minor subject course for graduate school students. Students in this course must take more subjects for completion in addition to major course subjects. Therefore our students have highly capable talents to achieve their purpose. We all have responsibility to protect our society from accidents/disaster. We expect our students will become strong leader with ethics for contributing nuclear safety.

4. Education network and Active learning

CSDRS have a network of the universities that have cooperated with related organizations to educate students as professionals with a higher sense of ethics. We have some lectuers using remote learning system. The students and the professors of universities from JNEN(Japan Nuclear Education Network) can make Q&A and discussions through wide monitors multi-directionally on the real time. [3]JNEN is associated with Okayama University, Tokyo Institute of Technology, Osaka University,Kanazawa University, Fukui University, Ibaraki University, Nagoya University and JAEA. But the remote learning doesn't have enough actual communication as compared to the normal lecture. We have developed and provided the summer session “Environments and Human Activities” for JNEN since 2010. This session is organized as a 5-day intensive course gathering students and teachers from the universities. We adopted active learning styles into this session. Active learning , for example group discussions, presentation and debate, are very important for students to develop a broad vision and to think for themselves. In addition, real communication makes a good relationship between students and teachers from each university. Total number of students who joined this summer session are about 150 during 6 years. Some students keep contact with each other after back to their universities. Figure 4 shows the photos of this session. Other class subjects that our center developed are ingenious to encourage students and have influence network universities.

Fig. 4 The summer session “Environments and Human Activities”

5. For the future generations

Most of our graduates progress to work for industry bringing their skill and knowledge to enhance industrial practices and safety environment. Personnel exchanges between companies and universities become more important. We also organized international work shop to educate students and young engineers in Figure 5. The graduate program has benefited from such as the international events. Younger faculty and graduate students should be encouraged to participate at these events.

In Japan we have experienced severe accident in FUKUSHIMA NPP. How should we do to prevent accidents? How can we protect people from natural disasters? We must continue to question and remember our experience for future generations. Safety education and training could be a part of solution. But considering back ground of safety problem, we can’t find the way to prevent accidents. Recently there have been rapid generational changes in the workers all over the world. Inheriting technology and past accomplishments in Nuclear facilities are essential for enhancing safety management. The concept of Risk should be understood for all stakeholders. To construct a safety culture for all persons, safety education is especially important. Because safety culture exists in people’s minds. To enhance public understand of nuclear safety, we will host a number of lectures for companies, industries and all stakeholders. We believe this will further enhance stakeholder knowledge and the reach public communication.

Fig. 5 International Workshop

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What are the tools recently developed for nuclear education and training?

THE IAEA'S INTERNET REACTOR LABORATORY PROJECT (IRL)

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ABSTRACT

The International Atomic Energy Agency (IAEA) is working with its Member States around the world to develop a variety of nuclear education and training opportunities. One of these projects is the Internet Reactor Laboratory (IRL) - a cost-effective way to remotely add an experimental component based on the use of a research reactor to university nuclear courses, where otherwise such an opportunity might not exist. The project offers a virtual capability in a remote location by linking a host operating reactor with university classrooms in neighbouring countries via the internet. In the actual stage of the project, IRL has been implemented in Europe and in Latin America and Caribbean region, while further extension of the project is foreseen in Africa and in Asia-Pacific. This paper presents the status of the IRL project and its implementation progress in each region.

1. Introduction

The International Atomic Energy Agency (IAEA) implements several international initiatives to support its Member States in acquiring access to high quality nuclear education and training opportunities. Even though it does not replace the effectiveness of hands-on training, internet based education and training has become a cost-effective option for complementing academic and vocational education. With this in mind, the IAEA has been working on the Internet Reactor Laboratory (IRL) project which aims at providing virtual access to research reactor experiments connecting, via the internet, an operating research reactor in a country with universities classes in other countries. For the IRL project, the IAEA is targeting countries that are interested in human capacity building for future nuclear reactor projects, and for countries that may want to pursue non-power applications of nuclear technology such as nuclear medicine or nuclear research in general.

The project has been implemented in Europe, with the Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA) and its ISIS research reactor, and in Latin America, with the Comisión Nacional de Energía Atómica (CNEA) and its RA-6 research reactor. Further extension of the project is foreseen in Africa and in Asia-Pacific. This paper describes the status of the IRL project and its implementation progress in each region. It describes successively the concept of the IRL, the status of the IRL implementation in Europe and in Latin America, and the future programme to expand the IRL capability world-wide.

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2. The IRL Project

The IAEA has various activities in the area of nuclear education and training for the development of the human capacity using research reactors. The IAEA, mainly via the Peaceful Uses Initiative project 'Increasing the Global Supply of Nuclear Education and Training Programmes Through Research Reactor Facilities' supported by extra budgetary funds from the US Department of State, is developing the IRL project which aims at providing virtual access to research reactor experiments, connecting, through the internet, an operating research reactor in a country (host reactor) with universities classes in other countries (guest institutions).

The concept of the IRL project was pioneered internationally in 2010 through a link from the PULSTAR research reactor of North Carolina State University to teaching classes at the Jordan University of Science and Technology [1]. Following this first experience, since 2012, the IAEA decided to launch the IRL project which is intended to increase the global supply of nuclear education based on the use of research reactors.

The IRL offers an additional option to access operating research reactors around the world and carry out education and training activities through the internet. Such a project delivers its maximum benefit to countries that are engaged in human capacity building for future nuclear programmes (power and non-power) but that do not have access to suitable research reactor facilities. The IRL project is aimed at advanced undergraduate or postgraduate level nuclear engineering or nuclear physics students. The following paragraphs give the status of the IRL project in the different regions of the world.

3. IRL implementation in Europe

For the implementation of the IRL project in Europe, the IAEA has been working with CEA since 2013. Based on discussions and thanks to the demonstrated experience and availability of the ISIS reactor in the area of nuclear education utilizing research reactors, this facility has been selected to act as a host reactor of the IRL project mainly in Europe but also for a few countries in Africa at this stage of the project.

The ISIS research reactor is an open core pool type reactor, with a nominal power of 700 kW. This facility is an essential tool for the education and training programmes organised by the National Institute for Nuclear Science and Technology (INSTN), a higher educational institution integrated to CEA. A large panel of training programmes with variable durations ranging from 3 to 30 hours are being regularly conducted at the ISIS reactor (400 trainees a year) [2].

In 2014, the INSTN integrated an advanced videoconference system on the ISIS reactor. The decision to go for the transmission of only video signals out of the controlled computer from the supervision system was dictated by security issues. It also gives the advantage of making the reception and display of the information at the guest institutions available with any standard videoconference system or software. The equipment implemented on the reactor includes a video conference system that can send in parallel two video signals. The schematic in Figure 1 shows the principle of the system that was implemented on the ISIS reactor.

The first signal corresponds to the signal of the camera from the video conference system. This camera, installed in the control room, is the main link between the team at the host reactor and the trainees at the guest institution.

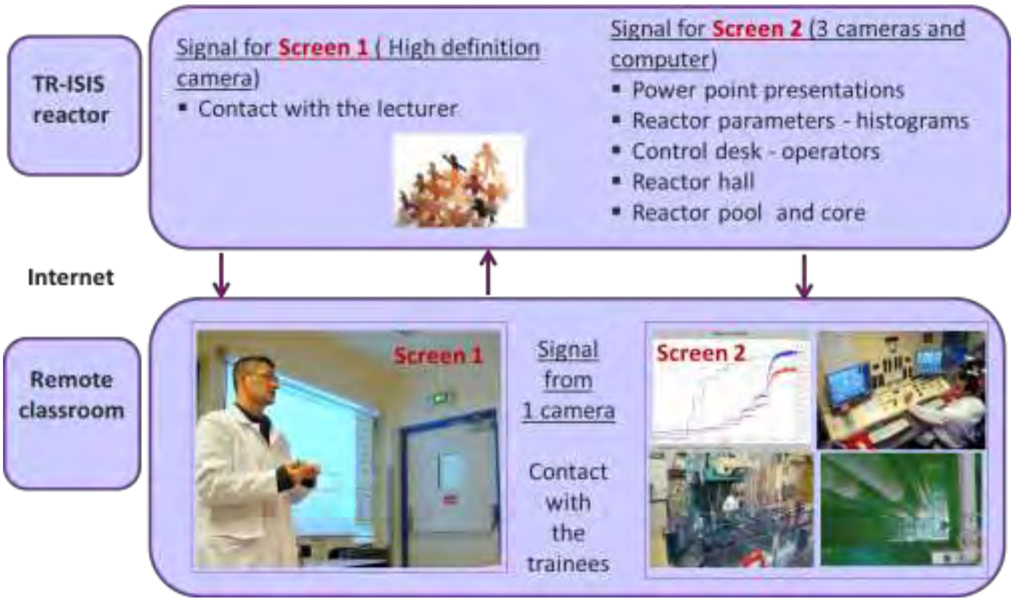

Figure 1: Schematic representation of the video conference signal and numerous screens implemented on the ISIS reactor.

The second signal comes from an internet broadcast dedicated computer that receives four different video signals: the video signal from the slave computer of the supervision system and the video signals from three cameras installed on the facility and looking at the reactor hall, in the core and at the control desk. Concerning the video signal from the slave computer, it can be used to show the following information:

- pages from the supervision system used to follow the state of the different systems of the reactor (control rods, detection systems, cooling system, safety system, etc.),
- graphs showing the time evolution of selected parameters for each experiment,
- power point presentation or other PC based materials,
- tables of selected data recorded by the supervision system,
- curves plotted using the recorded data after calculation,
- films to introduce or illustrate some experiments or phenomena.

Based on the particular experiment which is conducted (see for example Reference [3]), the host instructors can choose the images and information to be transmitted as a second video signal. The two signals, from the camera of the videoconference system and from the internet dedicated computer, are broadcasted to students and trainees through the internet. Thus, from a remote classroom the remote lecturer and trainees are able to follow the parameters of the reactor and to interact with the reactor team (host lecturer and operators) to conduct the experiment at the reactor facility.

Once a year, the CEA will perform and transmit the following reactor experiments:

- Lab 1: Fuel loading;
- Lab 2: Approach to criticality; Reactor start up; and Reactivity effect around criticality;
- Lab 3: Reactivity effect of devices (cylinders and box) placed in the core; Rod calibration curve; and Global worth by the rod drop technique;
- Lab 4: Role of precursors; Temperature effect; and Operating range of each detection system and associated OLC;
- Lab 5: Detection system in pulsed mode; Detection system in current mode; and Neutron flux measurements using a micro fission chamber – flux mapping.

Each experiment, with duration of three hours, will be broadcasted live from the ISIS reactor in parallel to a few guest institutions involved in the project. Currently, the confirmed countries as guest institutions to the IRL project are Belarus, Lithuania, Tanzania and Tunisia. Up to six guest institutions are expected to be able to join the experiments at the same time. In order to ensure the effectiveness of the laboratories, the host instructor/lecturer in the ISIS control room will conduct the laboratory and interact both with the operating team of the reactor and with the guest instructor/lecturer at each institution that will serve as the main interface with the students in the remote classroom.

During the year of 2015, the legal agreements between the IAEA and the guest institutions were finalized. All contracts have been signed with project counterparts in Belarus, Lithuania, Tanzania and Tunisia. Within the majority of these agreements, the IAEA has already provided financial support for the procurement of the equipment to the participating guest institutions.

A training and orientation workshop for professors from the guest institutions was organized by the IAEA at CEA Saclay in France in October 2015. The main objective of this workshop was to prepare the guest institutions for the first transmissions of the IRL experiments going through the following tasks, namely, to:

- provide on-site practical demonstration of the reactor experiments to familiarize the guest professors with the IRL experiments;
- train the guest professors on how to deliver the IRL experiments within their academic courses (technical and pedagogical aspects);
- share information on existing academic programmes both at the host and guest institutions;
- share experience and lessons learned on how to integrate these experiments into nuclear engineering and, eventually, nuclear physics curricula;
- discuss the technical and logistic issues related to the internet broadcasting system;
- discuss and develop the timetable for the transmission of the experiments during the academic year 2016/2017.

The workshop was attended by one or two professors from each guest institution and was leaded by five professionals from CEA. The professors invited to attend this workshop were future guest instructors who are expected to prepare the students and to teach the IRL experiments within their academic programmes.

The workshop was organized in such a way that, after a general presentation and visit of the ISIS reactor, the guest instructors attended and experienced the three first laboratories at the reactor, in the reactor hall or control room. This was a way for them to get familiar with the reactor characteristics, reactor operation, as well as with the recording and display of the reactor parameters carried out by the supervision system.

For the last two laboratories, the guest instructors attended the experiments in a video conference room next to the ISIS reactor. This was a practical way to train the guest instructors in having only the information broadcasted through internet for the delivery of the experiments at their guest institution. This test had a positive feedback from both host and guest participants. It showed that the information available through the internet connection together with the interactions between the host team and the guest instructors provided adequate information for the effectiveness of the IRL.

The workshop has been followed by connectivity tests carried out simultaneously from the ISIS reactor to the guest institutions, early in 2016. These will be followed by the broadcast of first test experiment, before the five core experiments will be performed and broadcasted to the students in autumn 2016.

4. IRL implementation in Latin America

To face the challenge to implement the IRL in Latin America, in April 2013, the CNEA and the IAEA signed an agreement on the establishment of the Internet Reactor Laboratory (IRL) project in Latin America, the CNEA RA-6 reactor in Centro Atómico de Bariloche – CAB (Argentina) being identified as the host reactor for the project. The agreement established the basis for the collaboration between institutions, defined the role of each partner, as well as the remote institutions participating in the IRL in Latin America and Caribbean region.

The RA-6 Research Reactor (Figure 2) was designed and constructed to support the teaching activities at the Balseiro Institute located in Bariloche, and was inaugurated on 26 of October of 1982. It is an open pool type reactor, 1MW thermal power, moderated and cooled by light water. The core, with possible variable configurations, is composed by MTR type fuel elements, originally HEU and then converted to LEU with 19.7% enrichment. As academic laboratory, the RA-6 has supported the education and training of hundreds Argentinian and foreign professionals as physicists, nuclear engineers, experts in radiochemistry and materials research.

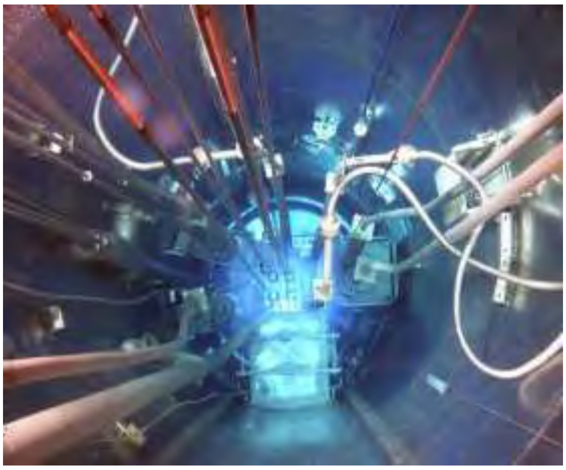

Figure 2: RA-6 pool, core, nuclear instrumentation, reactivity control system and other pool internals on the left. On the right, RA-6 reactor experimental hall and reactor block.

The main aspects of the agreement to establish the IRL Project in Latin America states that:

- IAEA financially supports the project, procuring the new equipment needed to establish the IRL in Latin America using the RA-6 Reactor as Host Reactor.

- IAEA covers the fee of each transmission to three guest institutions participating in the project for a period of 5 years.
- IAEA financially supports a training and orientation workshop for the principal instructors from the Guest Institutions
- CNEA, with its RA-6 Reactor acts as Host Institution for IRL project in Latin America.
- CNEA installs all the equipment needed to support the IRL project in Latin America and procures the internet infrastructure needed to support the IRL project in Latin America.
- CNEA develops the software and hardware to support the IRL project in Latin America.
- CNEA provides live video signals from the Host Reactor control room to facilitate interaction between the operator, students and instructors at Guest Institutions.
- CNEA broadcasts the six experiments (see list below) once a year during five years to the Guest Institutions.
- CNEA provides the necessary curriculum and laboratory protocols for each of the six core experiments to the Guest Institutions.

The six experiments to be broadcasted are:

1. Nuclear instrumentation in a research reactor;
2. Critical approach;
3. Control rod calibration;
4. Control rod reactivity measurement (rod drop);
5. Temperature reactivity coefficient;
6. Void coefficient calculation.

Initially, the agreement identified three potential guest institutions (in Cuba, Ecuador and Uruguay), while later was extended to seven guest institutions (one in Bolivia, one in Colombia, Universidad del País Vasco – Spain and Universidad Politectnica de Madrid – Spain), but maintaining a quota of three simultaneous guests attending the IRL session.

CNEA developed a platform to support the education at RA-6 in general and the IRL in particular: **the RA-6 Online**. The RA-6 Online follows the main principle of allowing the remote students to perform the experiments as if they were in the RA-6 Reactor itself. In order to do so, the signals of the RA-6 Reactor are replicated via internet to allow each remote student to follow the experiment on its own computer. A videoconference (VC) link is provided to allow, when needed, the interaction with the installation staff and professors. In a typical experiment the students follow the evolution of the reactor signals in their own computers or personal laptops and the instructor guides them through the physics and theoretical models and interpretation. In a screen they can see and hear the professor at the reactor site who interacts with the reactor operators and interprets any input, questions or requests of the students.

The RA-6 Online system has the following layers:

- Data acquisition is dedicated to acquire electrical signals representing the reactor operation variables. There is no possibility of control or perturbation of the reactor variables.
- Data management includes the databases and storing configuration, calibration and historical record.
- Data publishing contains a dedicated web platform developed to interact with the users in an intuitive and friendly way.
- Videoconference provides the link between the remote classroom and the reactor. The VC system contributes to the feeling of the remote students as if they were

present at the reactor building. The VC system also allows the local professors to guide the remote students in the development of the experience.

The RA-6 platform which was ready in March 2015 is under final testing with remote participants to start the transmissions on the second semester of 2016.

In September 2015, CNEA hosted a training and orientation workshop for the principal instructors from the Guest Institutions. Participants to the workshop included representatives from the IAEA and the main professors from the Universidad Mayor de San Andres (Bolivia), the Escuela Politécnica Nacional de Ecuador; the Universidad Nacional de Colombia; the Instituto Superior de Tecnologías y Ciencias Aplicadas (Cuba), the Universidad Politecnica de Madrid (Spain) and the Universidad del Pais Vasco (Spain).

During the workshop, the CNEA staff introduced the remote instructors to the RA-6 reactor as a nuclear facility. This activity was of great relevance in order to familiarize the remote instructors to the RA-6 reactor, the future laboratory of the experiments, etc. The CNEA staff presented the six protocols developed for the IRL in Latin America. The local and remote instructors analyzed the protocols and their implementation in the IRL platform. The host institution presented how they intend to include the IRL activities into the curricula at their national institutions. Finally the CNEA staff conducted two reactor experiments out of the six that will be transmitted within the IRL project, acting as local and remote instructors in order to demonstrate to the participants how the real sessions will be broadcasted by the IRL to the

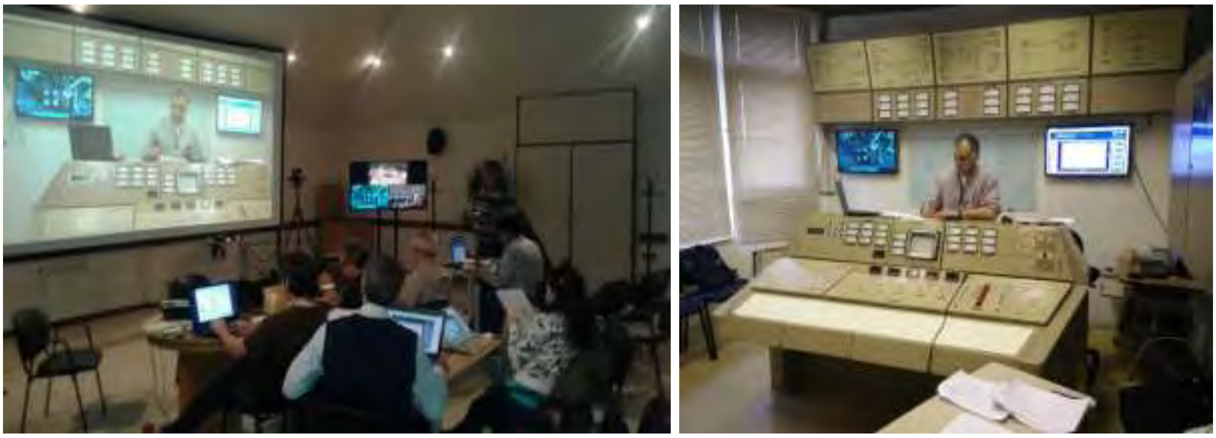

Figure 3: Transmission during the Orientation Workshop conducted in Bariloche, Argentina in September of 2015.

guest institutions in Latin America. Figure 3 shows on the left the remote setup with the instructors from guest institution performing the experience. It can be seen that each guest instructors has the complete set of transmitted signals on their laptops. On the right part of the same Figure 3, the local instructor from the CNEA can be identified conducting the experiment from the training control room at the RA-6 reactor.

Based on the availability of the RA-6 reactor and the academic curricula of the participating guest institutions at the training and orientation workshop, the participants agreed on officially commencing with the transmissions during the second semester of 2016

5. Further IRL implementation in Africa and Asia-Pacific

The IAEA has initiated some consultations and selection process has been started with a number of research reactors in Africa and Asia-Pasific regions. This process includes, mainly through dedicated expert missions:

- assessment of the national research reactor capabilities and its suitability to host the IRL for the regional partners,
- assessment of available human resources to support the IRL,
- review of contents and good practices performing reactor experiments,
- review related lecture materials and descriptions of practical exercises,
- confirmation of overall commitment by the national facility and funding authorities to support the IRL.

As a result of above assessment process and based on a number of comparative criteria, the best suited research reactors will be selected to host the IRL in Africa and Asia-Pacific regions, one reactor per region. The procedure will result in signing contractual agreements with these two host research reactor facilities.

In parallel, the IAEA encourages the participation and is collecting information from the Member States interested in receiving IRL courses through the internet. These interested guest countries, after signing the contractual agreements, will receive some financial support for the procurement of the required equipment to receive the IRL courses. The contractual agreements also include the offer to receive the IRL classes at no cost for a limited period of time.

It is expect that the IRL can start course transmission within Africa and Asia-Pacific regions in 2017.

6. Conclusion

The Internet Reactor Laboratory (IRL) appears to be a powerful tool, complementary to the on-site reactor training courses, for the development of the human resources needed for national nuclear programmes, power or non-power related. Keeping in mind that the virtual experiments will not be able to replace real hands-on experimentation at a research reactor, the IRL is seen as a cost-effective way to expand the nuclear education for groups of students or trainees that would not normally have access to a research reactor during their educational curricula. It can also help the IAEA Member States to better assess and quantify their human capacity needs for ensuring future (research or power) reactor projects. After the IRL's implementation on the ISIS reactor in Europe and RA6 reactor in Argentina is finalized, the periodic broadcasting of the IRL experiments will start in 2016. The first feedback obtained from the guest instructors, when being trained to use the information broadcasted in a remote classroom, has shown the effectiveness of the IRL experiments in getting a satisfactory insight into the reactor principles and operation. Thus the IRL is expected to provide a valuable contribution to the quality of the educational programmes at the guest institutions. The expansion of the project in Africa and Asia-Pacific regions is also undergoing, what ensures that the IRL will contribute to the increase in the global supply of nuclear education and training based on research reactors.

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NUCLEATING

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LANENT
Latin American Network for Education in Nuclear Technology

ABSTRACT

The project is divided into three parts, “cards” of nuclear content, didactic sequences and teacher training. In a first step, the cards and the didactic sequence corresponding to the Nuclear Physics group is developed. The rest of the didactic sequences are developed in the period 2016/19.
The cards on the front contain an explanation of the issue and on the back an image and / or graphics illustrating the subject. To expand the content we added QR codes that link to audiovisual material that explains the issue. The didactic sequence developed on the set of tabs of Nuclear Physics, has five activities that include the use of ICT for resolution. We incorporate Java simulations, multimedia resources and augmented reality in the activities.
The project includes an instance of teacher training. In the workshops the questions and concerns that arise in the different activities are answered and resolved together with some advice on the implementation of the technology necessary to bring to the classroom the activities.
In the project, carried out in Argentina, the cards were made and activities are created within the institutional website space "Educational Content". For those teachers who want to develop classroom activities and an Internet connection enables the teachers to do so online. The trainings were conducted in the Province of Formosa, Salta, Tucumán, Córdoba, Río Negro and Buenos Aires City.

1. Introduction

The project stems from an initiative by the Department of Press and Communications, belonging to the Management of Social Communication of the National Atomic Energy Commission (CNEA) to generate educational content that covers the nuclear issue and can be used as reference material and consultation in the classroom. While there are initiatives linked to the disclosure of these issues in schools, this project seeks to generate its own theoretical material, supported by professionals working in CNEA and to become a source of permanent consultation for teachers who want to address issues of nuclear physics in the classroom.

From this experience it the aim is to replicate the project at regional level, to reach the entire area of influence of LANENT.

LANENT the project is divided into three parts, the first one is the creation of cards with educational content, the second one is the realization of didactic sequences and the last one is the creation of training workshops for teachers.

The objective set is to provide educational materials, activities and training for teachers of physics and chemistry of the average level of education in Latin America and the Caribbean on issues of nuclear physics for to work in class.

1. Development

The project is based on the cooperation of member countries LANENT for generating the content at all stages of the project; this content must reflect the reality on the nuclear issue of the whole region. For the process of collection of theoretical material the LANENT Virtual Campus is used and communications is established via e-mail. Within the Campus there are discussion forums, chat rooms and wikis for each topic that is being developed.

2.1 Cards

They are a consulting resource for mid-level teacher education. There are twenty-five cards of 15 by 21 cm. The front has one thousand characters. And the back has five hundred typefaces, graphics or explanatory scheme.

Topics covered: Institutional, radiation protection, nuclear physics, nuclear fuel cycle, reactors, applications, environmental impact.

The design must respect and be in line with the corporate image of LANENT.

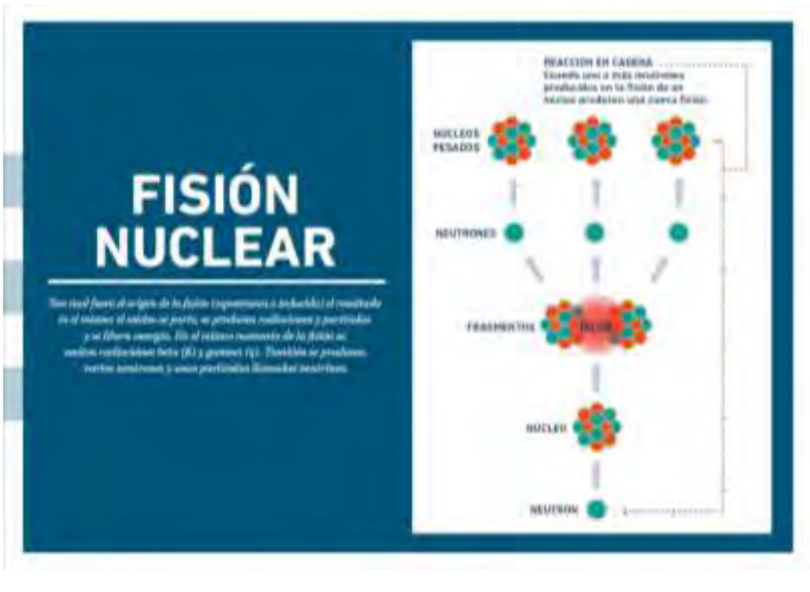

Figure 1. Back of card - Nuclear Fission

Figure 2. Back of card - Reactors

Figure 3. Container pack

Institutional
What is LANENT?
Formation and Training

Radiological protection
Interaction Radiation - Matter
regulations
regulatory

Nuclear physics
Energy
Atom
Fission
Fission Energy
Radiation
Radioisotopes

Nuclear Fuel Cycle
Mining
Manufacturing Fuel
applications

Reactors
Power
Investigation

Applications
Nuclear medicine
Industry
Agro
Preservation of documents
Nuclear Techniques: Food
Nuclear Techniques: Water

Environmental impact
Environmental protection
Waste Management
Climate change

Figure 4. Issues of Cards

2.2 Didactic Sequences

The didactic sequence is presented as a series of activities linked to official syllabi. It is intended as a suggestion to apply in class, is it distributed under Creative Commons license, and teachers can modify and adapt the activities to take them to their classes. The didactic sequences are designed to use with netbooks and / or PC, and have a high technological content which allows the use of computers for resolution ([1]). QR codes, interactive simulations in javascript, and augmented reality are included. All resources and programmes can be downloaded to work offline in cases that do not have a good Internet connection.

2.3 Teacher training Course

We have planned a training course for teachers, "nuclear activities in the classroom" where teachers are trained in solving activities containing the teaching sequence of nuclear physics. A part of the course is designed to reflect with teachers about the problems in the teaching / learning different strategies which are analized and reverse-class method is explained. Web 2.0 tools for creating interactive audiovisual resources with nuclear material content to finish preparing a class under this method.
The training that we will implement in this project responds to teacher trainers model. The idea is to train teachers who can run these workshops throughout the LANENT region.

2.4 Scheme and work schedule

We have formed a team with members from several Latin American countries: Argentina, Chile, Brazil, Bolivia, Peru, Venezuela, Uruguay, Mexico and Cuba.

Representatives of these countries are responsible for sending in the theoretical material of different topics to be developed.
There are priority groups to develop cards; these are the groups of Nuclear Physics and Applications. This group of cards and activities was made in 2015.
The final version of the cards will be developed by an professional who will shape the content sent by members of the various countries of the region to adapt to the tab format. Both the illustrations and infographics as the format and design of the cards will be in charge of graphic designers, who must respect the visual identity manual LANENT.

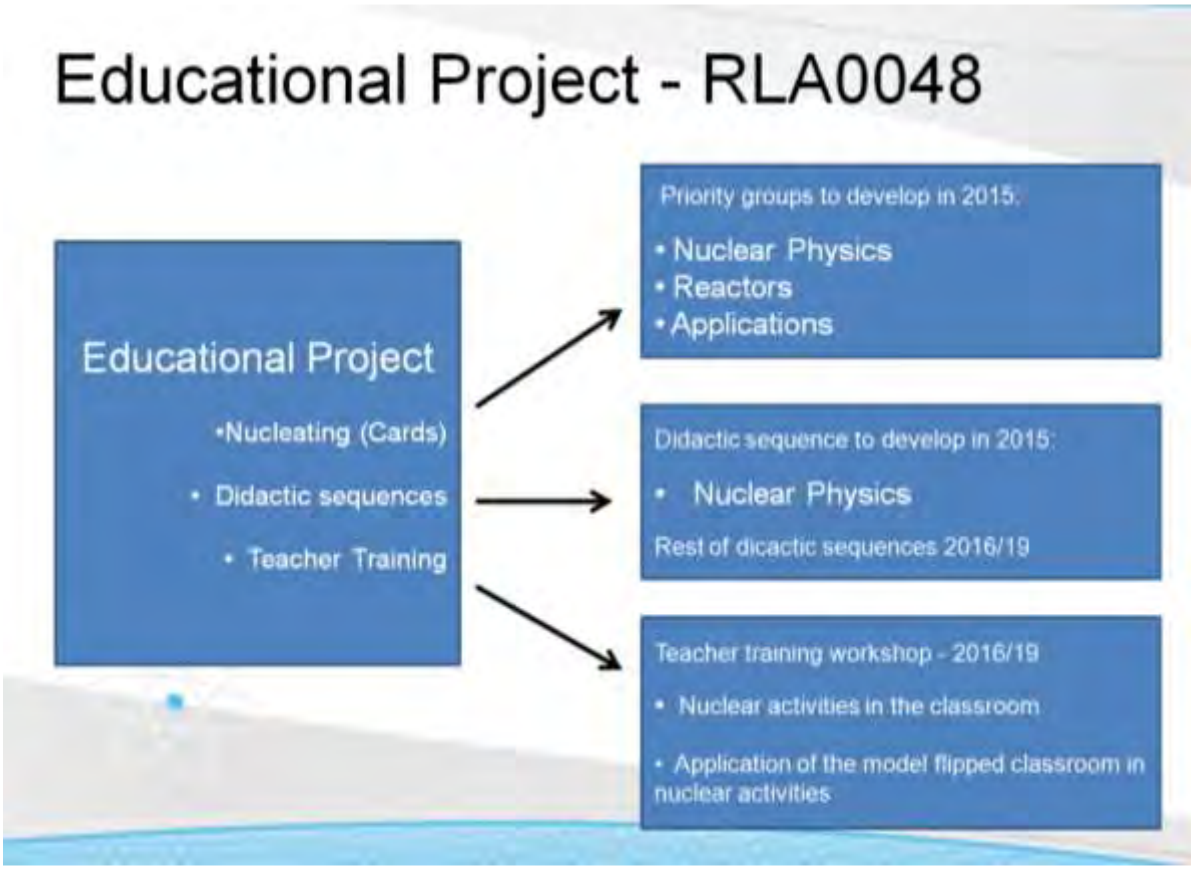

Figure 5. Diagram of the Project.

2.5 Experience Argentina

The original project in Argentina, on which the work the LANENT is based, was conducted in 2014. It was created to address the need to occupy a place in the classroom, giving teachers a reference that can used to work the nuclear issue. This emerges from a look at the conceptual errors that were in the textbooks used in the different schools.
The project involved the realization of twenty chips, the teaching sequence for the group of cards nuclear physics and teacher training workshops.
The model of teaching sequence presented in Argentina respects the format of teaching programmes offered to teachers on sites like “Conectar Igualdad (2)” or “Educ.ar”,

mentioning the general objectives, the aims of the activities and issues related to the official curriculum.

Figure 3. Example of Cards (Argentine version)

Teacher training workshops has been presented in the provinces of Formosa, Salta, Tucuman, Cordoba, Río Negro and Buenos Aires. After each workshop teachers completed a survey that assesses different aspects of the delivered material and the training offered. In the Argentina version the cards were printed, which allowed us to give the teachers a package to work with during the workshop and in case you want to bring activities into the classroom we send several sets of cards so that the teacher can work in class.

Final Thoughts

The project presents several challenges, one is to integrate this material for secondary schools, and the reality of the nuclear issue in the region of Latin America and the Caribbean. Then there is the challenge of presenting this material as an option in the different educational contexts of LANENT member countries of the network and integrate to the various national plans (1 to 1 models). The training teachers, within the project, gives us the opportunity to approach an institutional actor of great importance within the educational community, working together with each teacher in the context of the workshops strengthens the chances of inclusion of these issues in class.

It is a long term project that involves a joint effort of many professionals in the region that allows cooperation and interaction for a common goal, which is to install the themes of nuclear physics in the classroom, accompanied by a technological proposal that allows training and enable students approach these issues, teaching them with the technologies that they use when they join the labour market.

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PyNIC: Python-Based Neutron Interaction Calculator for Accurate Neutron Activation Predictions for TRIGA Experiments, Students Training and Education

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ABSTRACT

The Python-Based Neutron Interaction Calculator (PyNIC) is an in-house developed software for predicting the neutron activation of an irradiated sample. PyNIC is different from other neutron activation analysis (NAA) predictive tools in that it solves the activation equation by integrating across the entire neutron energy spectrum and radiative capture cross section data, instead of only using a few selected neutron capture cross section values as often found. This novel tool allows for the prediction of activities and dose rates of samples irradiated in the University of Utah TRIGA Reactor (UUTR) to a highly accurate level not obtainable by other tools. PyNIC has a simple graphical user interface (GUI) that allows the user to select the neutron energy spectrum, the neutron flux (of a research reactor) to which the sample will be exposed, the guessing nuclides present in the sample and their known or estimated relative abundances. Next, the user enters the sample mass, irradiation time, and sample waiting time (during which the sample activity will be reducing to allowed levels) for the NAA experiment to take place. PyNIC is also applicable to other facilities where NAA is performed because additional information as needed can be easily added to the code. Irradiations of metal wire samples in the UUTR are performed to benchmark PyNIC. These irradiations are based on reactor power levels ranging from 1 – 90 kW; the activated samples are then measured using a high purity germanium (HPGe) detector. Early results show that PyNIC predicts the activity of Ni, Ti, and Co samples within the expected experimental error margins.

The PyNIC is used as a standard training for all students entering the education and training programs in nuclear engineering classes. Students use PyNIC as part of laboratory practice in addition to a required pre-step in planning for every NAA experiment assuring safe outcomes and well-optimized NAA experimental conditions and associated parameters.

1. Introduction

Neutron activation analysis (NAA) is a technique used to perform qualitative and quantitative analysis of many different elements in a sample. It is used in many different fields of science including forensics, mining, geology, etc. and is favorable for element analysis because it is non-destructive and very accurate (Trkov, 2015). When certain elements are irradiated, typically in a nuclear reactor, nucleus in the sample will absorb a neutron creating a daughter nuclide; often times this daughter nuclide is in an unsteady state and will release the extra energy through radioactive decay, accompanied with the emission of gamma rays. The emission of these rays is critical for NAA, as they are unique to the nucleus. These gamma rays are then detected with the detectors (usually high purity germanium, HPGe) to identify the parent nucleus.

A crucial practice in ensuring the safety of the NAA user is predicting the activity and the resulting dose rate that a sample will produce after it has been irradiated. There are various NAA software programs existing for this purpose of pre-calculation of activity and dose rate of NAA experiments (WISE Uranium Project, 2012), (NIST, 2015), (Sahin, 2008). The majority of these programs use only one or just a few neutron energies (typically the energy of thermal neutrons) in their activity calculations, often disregarding the range of different neutron energies present in the irradiation ports where the sample are positions. When these energies are not included, the number of neutrons and the resulting activity level is inaccurately represented, leading to discrepancies in predicted values of activity and measured doses following removal of the sample from the reactor. In extreme cases, this may lead to exceeded radiation exposure limits. In addition, most of these tools are not user-friendly and lack a self-explanatory running platform, and thus are impractical as a teaching or training tool (Landsberger, 2005).

These limitations are addressed by the software as presented in this paper; it is named the Python-based Neutron Interaction Calculator (PyNIC). The PyNIC is tested at the Utah Nuclear Engineering Program (UNEP) research reactor and is an integral part of the daily NAA activities as well as training of the students and the facility users.

2. Methods

The PyNIC is unique because the entire neutron energy spectrum is used to calculate a sample's activity by integrating across the entire region for the radiative capture cross section, thereby significantly increasing accuracy. Thea PyNIC is open source code, and simple to learn, allowing it to be used in classroom settings as a teaching and training tool. With the PyNIC software the activity produced from the daughter nuclide in NAA experiment is calculated as follows:

$$A_D(t) = m\left(\frac{N_A}{A_m}\right)A_{\%}\left(1 - e^{-\lambda_D t_{irr}}\right)e^{-\lambda_D t_{decay}}\int_0^{\infty}\Phi(E)\sigma_p(E)dE \qquad (1)$$

where:

Φ – neutron fluence (add unit here) with kinetic energy E $(\frac{n}{cm^2 * s})$
E – Emitted gamma ray energy (MeV)
σ_p–parent nuclide radiative capture cross-section for neutrons with kinetic energy E (cm^2)
m – mass of sample (g)
N_A – Avogadro's number
A_m – atomic mass $(\frac{g}{mole})$
$A_{\%}$ - atomic abundance ratio
t_{irr} – irradiation time $(secs)$
t_{decay} – decay time $(secs)$
$A_D(t)$ – activity of daughter isotope (Bq)
λ_D – decay constant of daughter isotope (s^{-1})
A_D – activity of daughter nuclide (Bq)

The activity calculated from Eq. (1) is then used to calculate the expected dose from the sample:

$$Dose\ Rate\ \left(\frac{mrem}{hr}\right) = \frac{A_D(R)E(\frac{\mu}{\rho})*(1.6*10^{-13}(\frac{J}{MeV}))(1000\ (\frac{g}{kg}))(3600\ (\frac{s}{hr}))(10^5(\frac{mrem}{\frac{J}{kg}}))}{4\pi r^2} \quad (2)$$

where:

R - ratio of decays from a given isotope that emit a gamma ray of that energy (branching ratio)

μ/ρ - mass energy-absorption coefficient ($\frac{cm2}{g}$)

r - distance from source (cm); in the case of PyNIC it is 30.48 cm.

The PyNIC has an average running time of less than one second providing therefore an effective and human error free pre-experimental design of safe and accurate NAA experiments. This is significant because different parameters such as sample irradiation time, selection of the reactor irradiation facility, required sample decay time, and reactor power, can be adjusted before the experiment to assure that reasonable and safe activity levels are produced.

Although the technical specifications at the UUTR do not contain a maximum dose rate limit allowance for experiments, in order to keep radiation exposure as low as reasonably achievable, PyNIC is necessary to adjust experimental parameters to optimize the experiment. At the UUTR the dose rate produced by the products of an experiment is measured at a distance of 30 cm immediately after it is taken out of the UUTR. This dose measurement is done by a pressurized ion chamber Ludlum model 9Dp-1 and recorded. If the dose rate is designated to be too high by the reactor operator the experiment is re-placed back into the reactor tank and allowed additional time to decay to safer radiation levels. Using the PyNIC before an experiment has helped minimize these occurrences of early removal and re-placement.

3. Materials

The PyNIC is written in Python programming language, and is adjusted by the user via a graphical user interface (GUI) developed using the tKinter library. The PyNIC plays an important role in the teaching of NAA in the Utah Nuclear Engineering Program Facility; before students are allowed to perform an NAA experiment they learn the PyNIC and the calculation approach and compare to the theoretical methodology. They then compare their hand theoretical methodology-based calculations to the PyNIC results.

The PyNIC library contains over 250 nuclides with the entire radiative capture cross section data, half-life, and gamma ray energies collected from the KAERI database of nuclide information (http://atom.kaeri.er.kr/). The values found in the ENDF-VII at 300 K library are used. Since the PyNIC is an open source code, additional nuclide data can be added to the existing PyNIC nuclear data library as needed.

The PyNIC software is accessed from one, simple-to-use GUI as seen in Figure 1. The ease of adjustment for each necessary parameter makes PyNIC user-friendly and efficient. Sample mass, irradiation time, decay time and sample guessed elemental percent abundances are inputted directly, while nuclide identity and neutron flux have choices displayed by a drop-down menu option. Up to ten different nuclides may be entered for calculation in a single experiment. Each nuclide must have its percent abundance value inputted; once this data is all present, the calculations are performed by pressing the RUN button. Figure 2 shows an example of the PyNIC GUI input data used to calculate reactivity and dose rate of the NAA experiment complied into a text document.

One of the input parameters of PyNIC is neutron flux, or the corresponding reactor power level. The UUTR has four irradiation facilities where NAA can be performed. These facilities include the Thermal Indicator (TI), Central Indicator (CI), Fast Neutron Irradiation Facility (FNIF), and pneumatic irradiation

(PI). At each different irradiation facility location, there is a different amount of neutron flux that a sample will receive, thus changing the amount of activation a sample will undergo in each location. The difference between the irradiation ports is that the TI is located on the edge of the reactor and is surrounded by a tank of deuterium. Therefore the TI has a higher relative thermal neutron component than the PI and FNIF. The FNIF is also located on the edge of the reactor core but it does not have the surrounding deuterium, therefore it has a larger fast neutron component than the TI. Also, the FNIF can accommodate much larger samples than any other irradiation facility. The PI is located within the reactor core where it has a larger fast neutron component than the TI. The appropriate irradiation port may be selected within PyNIC to determine the NAA results based on the neutron flux in each irradiation port. The neutron energy spectra for the UUTR irradiation ports are simulated using MCNPX (Goorley, 2012) which can be seen in previously submitted work (Moffit, 2014). This is a desired addition to the PyNIC software as it allows more accuracy using reactor flux across the entire energy spectrum rather than just at one specific energy.

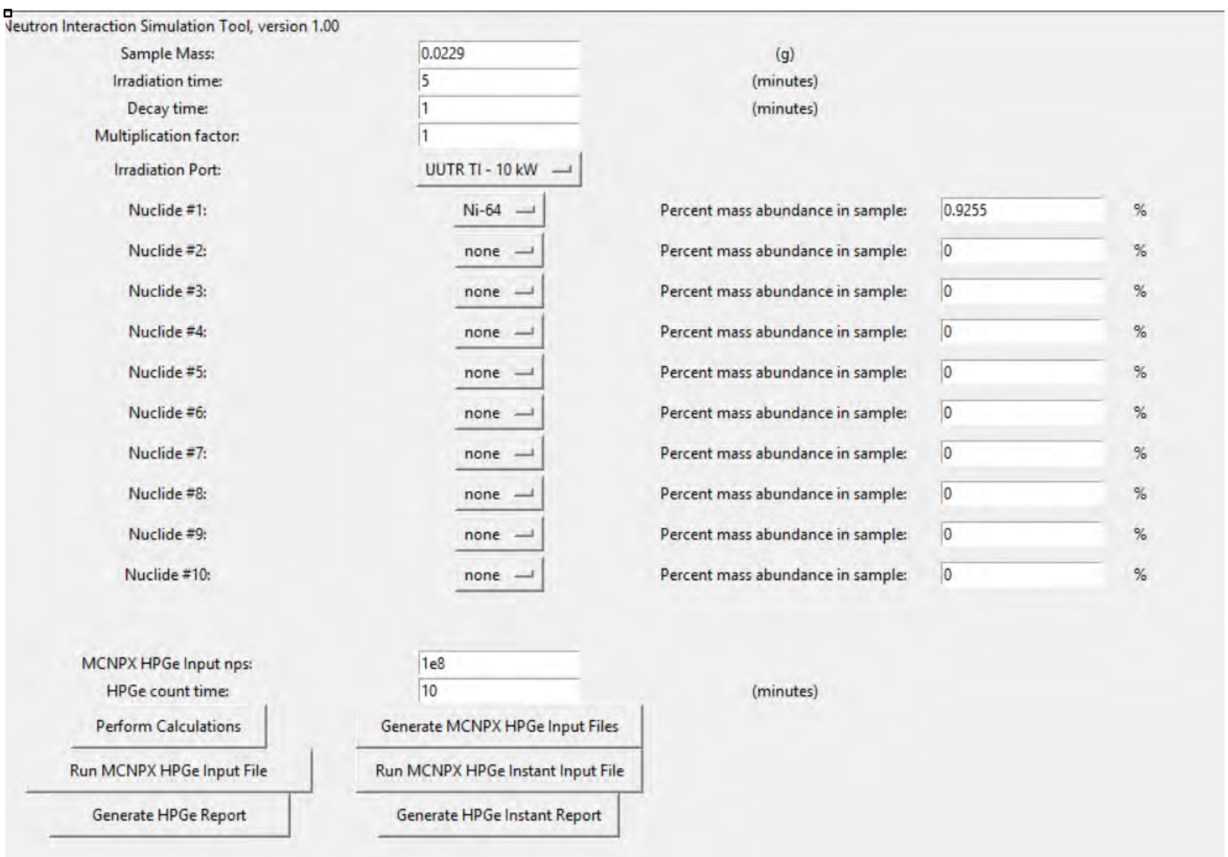

Figure 1 PyNIC: GUI showing the experimental parameters for Nickel wire: sample mass, irradiation time, decay time, and percent mass abundance in sample. The UUTR irradiation port and nuclide are selected from the drop down list options.

A number of NAA experiments are performed to test the PyNIC. The basic experiments include irradiating various types of metal wires at specific UUTR power levels in the thermal irradiation port of the UUTR and then counting their activities using an HPGe detector. The experimental results are compared to activity predictions from the PyNIC with the same experimental parameters. The metal wires that have been irradiated to date are Ni, Ti, Co, and W. The experimental parameters for these irradiations are shown in Tables 1-4. Each metal used has a varying number of NAA experiments that were performed for them, being limited by the amount of wire available. In the case of cobalt, the daughter product is long-lived, so fewer activated samples are desired. Additional replicates of certain experiments were performed in order to resolve uncertainties in measured values.

```
==============================================================
UNEP NAA Calculator Version 1.01B 11-August-2014
==============================================================
Sample Mass: 0.0229 g
Irradiation Time: 5.0 min
Decay Time: 1.0 min
Neutron Beam: UUTR TI - 10 kW
Table 1. Activation Products
============================================================================
Nuclide          Activity (mCi)       Activity (uCi/g)      Half-life (minutes)
============================================================================
Ni-65            8.95795386445e-05      3.91177024648         151.032
none             0.0                  0.0                   0.0
none             0.0                  0.0                   0.0
none             0.0                  0.0                   0.0
none             0.0                  0.0                   0.0
none             0.0                  0.0                   0.0
none             0.0                  0.0                   0.0
none             0.0                  0.0                   0.0
none             0.0                  0.0                   0.0
none             0.0                  0.0                   0.0
Total            8.95795386445e-05

Table 2. Calculated Dose
==============================================================
Nuclide          Dose Rate (mrem/hr)
==============================================================
Ni-65            0.000514027723393
none             0.0
none             0.0
none             0.0
none             0.0
none             0.0
none             0.0
none             0.0
none             0.0
none             0.0
Total            0.000514027723393

Table 3. Gamma Emissions from Ni-65
=========================================================================
Gamma Energy (MeV)     Decay Ratio (per radioactive decay of Ni-65)
=========================================================================
```

Figure 2 PyNIC: Text file screenshot of generated report for nickel experiment

Sample	Sample mass (g)	TI Power (kW)	Irradiation Time (min)		Sample	Sample mass (g)	TI Power (kW)	Irradiation Time (min)
1	0.1444	1	3		10	0.1041	50	3
2	0.1046	1	3		11	0.1025	50	3
3	0.0997	1	3		12	0.1024	50	3
4	0.1021	10	3.57		13	0.1016	70	3
5	0.1035	10	3.57		14	0.1017	70	3
6	0.1101	10	3.57		15	0.1020	70	3
7	0.1025	30	3		16	0.0954	90	3
8	0.1023	30	3		17	0.1024	90	3
9	0.1029	30	3		18	0.1021	90	3

Table 1. Nickel wire sample irradiation parameters

Sample	Sample mass (g)	TI Power (kW)	Irradiation Time (min)		Sample	Sample mass (g)	TI Power (kW)	Irradiation Time (min)
1	0.0235	1	5		12	0.0232	50	5
2	0.0227	1	5		13	0.0229	70	5
3	0.023	1	5		14	0.0232	70	5
4	0.0229	10	5		15	0.0229	70	5
5	0.0231	10	5		16	0.0228	90	5
6	0.0235	10	5		17	0.0227	90	5
7	0.0226	30	5		18	0.0233	90	5
8	0.0238	30	5		19	0.0235	90	5
9	0.0236	30	5		20	0.0227	90	5
10	0.0237	50	5		21	0.023	90	5
11	0.0226	50	5					

Table 2. Titanium wire sample irradiation parameters

Sample	Sample mass (g)	TI Power (kW)	Irradiation Time (min)		Sample	Sample mass (g)	TI Power (kW)	Irradiation Time (min)
1	0.0091	10	60		6	0.0085	50	60
2	0.0085	10	60		7	0.0081	90	60
3	0.0085	10	60		8	0.0084	90	60
4	0.0092	50	60		9	0.0083	90	60
5	0.0081	50	60					

Table 3. Cobalt wire sample irradiation parameters

Sample	Sample mass (g)	TI Power (kW)	Irradiation Time (min)		Sample	Sample mass (g)	TI Power (kW)	Irradiation Time (min)
1	0.1274	1	1		10	0.1337	50	1
2	0.1575	1	1		11	0.1346	50	1
3	0.1615	1	1		12	0.1135	50	1
4	0.1757	10	1		13	0.114	70	1
5	0.139	10	1		14	0.1196	70	1
6	0.1099	10	1		15	0.1044	70	1
7	0.1533	30	1		16	0.119	90	1
8	0.1317	30	1		17	0.0936	90	1
9	0.142	30	1		18	0.1013	90	1

Table 4. Tungsten wire sample irradiation parameters

4. Results

The measured activities of the irradiated metal wire are compared to the PyNIC predicted values and shown Tables 5-8. Results in the tables demonstrate that there is still variability in the NAA experiments and that the relative error on the measured values needs to be improved in order to provide a better benchmark for the PyNIC. There are some potential remaining inaccuracies in the

PyNIC, likely due to the neutron flux from the MCNPX simulation of the UUTR. Additional refinement of the MCNPX model of the UUTR is expected to lead to a better representation of the actual flux in the irradiation ports. It can be seen from Table 5 and Table 6 that the Ni and Ti results all match within 8.51% accuracy- many of the predicted values falling within 3-4% of the measured values. From Table 7 and Table 8 you can see that Co and W results have relative errors of 20-30%. It is believed that the discrepancies between predicted and measured results are due to either inaccuracies in the NAA experiments or an insufficient level of detail in the MCNPX simulation of the UUTR.

Reactor Power (kW)	Measured Activity (uCi/g)	PyNIC Activity (µCi/g)	% Difference
1	0.23405	0.251288	7.37%
10	2.76806	3.003748	8.51%
30	7.47354	7.589389	1.55%
50	12.76382	12.64989	-0.90%
70	17.51035	17.70857	1.13%
90	21.89897	22.76817	3.99%

Table 5. Nickel NAA Result Compared to PyNIC

Reactor Power (kW)	Measured Activity (uCi/g)	PyNIC Activity (µCi/g)	% Difference
1	3.84	3.787	-1.37%
10	38.96	37.87	-2.80%
30	111.38	113.62	2.01%
50	202.08	189.36	-6.29%
70	263.80	265.10	0.49%
90	326.34	340.85	4.26%

Table 6. Titanium NAA Result Compared to PyNIC

Reactor Power (kW)	Measured Activity (uCi/g)	PyNIC Activity (µCi/g)	% Difference
1	6.66	7.72	23.11%
50	34.80	38.61	17.70%
90	61.46	69.50	17.03%

Table 7. Cobalt NAA Result Compared to PyNIC

Reactor Power (kW)	Measured Activity (uCi/g)	PyNIC Activity (µCi/g)	% Difference
1	1.50E+00	1.20E+00	24.60%
30	1.36E+02	1.04E+02	30.55%
50	7.54E+01	7.38E+01	2.20%
70	1.06E+02	8.35E+01	26.46%
90	1.36E+02	1.06E+02	27.92%

Table 8. Tungsten NAA Result Compared to PyNIC

5. Conclusions

The PyNIC software is a very beneficial addition to the Utah Nuclear Engineering Program. It is a great teaching tool used in classrooms to understand neutron activation analysis, and it greatly increases the safety of neutron activation analysis experiments done in the University of Utah TRIGA Reactor. Estimating activity levels and dose rates before an experiment is begun assures that the activity levels of the products of an NAA experiment are never above the safe dose limit threshold. PyNIC currently is producing calculations for activity that are within an 8.51% difference of the measured activity for Ni and Ti experiments and within a 30.55% difference for Co and W experiments, to improve the accuracy, MCNP simulations which more accurately depict the UUTR are being produced and used in the PyNIC software. The PyNIC is still in its early years of development with plans for expansion and growth. Currently, more benchmarking experiments are being performed to calculate the accuracy for various other elements, simulations are being created to expand this software for all irradiation facilities in the UUTR, and a website being created where this software can be accessed by anyone. Next steps for the PyNIC are to expand the applicability of this software for all research reactors, which will greatly improve the safety of nuclear science on the academic level.

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COULD CREATIVITY BE TAUGHT AND EVALUATED IN A NUCLEAR ENGINEERING COURSE?

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Abstract

Creativity is usually defined as the capability of generating ideas or products that are new, useful and that have an impact. This looks like a very important aspect in an engineer's life. Some authors relate creativity and intelligence till the point of discussing if they are in fact the same thing.

On the other hand, creativity has never been a top issue in engineering education. Trying to overcome this limitation, the Technical University of Madrid (UPM) is studying ways to introduce students to creative thought in their technical subjects. The subject selected for this project is Nuclear Power Plants.

Creativity is a skill, but most of the studies suggest that creative thinking can be learned, practiced and improved. Accordingly creative thinking is taught through several exercises. The main exercise to stimulate lateral thinking was a role-play activity. In this activity the students had to defend a NPP type against other types simulating they are the selling company in an oral presentation. A role-play activity enhances creative thinking because it forces students to look for arguments and new ideas for defending that NPP against others, even though that type is not their preferred. The other way chosen is the application of the Socratic method during the exposition of the lessons in the class.

Creativity is normally hard to evaluate objectively. In this aspect, in Nuclear Power Plants, the creativity is evaluated indirectly. The final written exam have a question about an accident in a NPP that has never been thought in class and the students have to infer how the plant systems will behave. They need technical information and creative thinking as well to answer properly to this question.

In this first approach to creative thinking the students have a positive feedback, considering creativity a very important skill for their future. In future courses, maybe a more powerful creativity evaluation will be included like the C-SAT. As a conclusion, it is clear that creativity has arrived to engineering schools to stay.

1. Introduction

1.1. Defining Creativity

Creativity is usually defined as "the ability of generating ideas or products that are new, appropriate and that have impact" [1], [2], [3]. The characteristic appropriate refers to useful products or ideas; In the art field this term could be replaced with the term beauty. Accordingly, new products that are not useful or vice versa should not be considered creative.

However, a person's creativity is a concept that still resist to be defined unilaterally by the scientific community. If a person's creativity is taken as the sum of the creativity of all of his/her products or ideas, when it is supposedly evaluated though a test, creativity is not really evaluated but the creative potential of a person, [4]. For this reason, hereinafter when creativity is mentioned in that sense, what is meant is creative potential.

It is interesting to wonder if this creativity potential could be really measured with tests or interviews. Several studies argue that evaluating it is not only possible but also accurate. [5], [6], [7]. Even though creativity is usually separated from intelligence as non-related capabilities, [8], [9] it is not easy to isolate one from another for its specific evaluation, in fact in a typical test of IQ, creativity plays an important role in its scoring. There are even some authors that relate intelligence and creativity until the point of wondering if they are in fact the same thing [10].

Creativity is also part of a person's personality and skills; this is supported by some studies [11], that suggest that there are common characteristics between highly creative individuals such as introversion, ambition or impulsivity.

1.2. Developing creativity

Authors like Davies [12] affirm that a very effective way of teaching creativity in the classroom is by teaching creatively. This means that for enhancing creativity in the students it is not mandatory to make specifically-designed exercises for it, it is possible to train creativity in the classroom while teaching technical content as long as the teaching is creative.

As an example, instead of using an expositive technique and a simple power-point, it is more adequate to use a group performance, debates or brainstorming for specific topics that require the student to think for himself/herself for unusual or outside-the-box solutions to certain problems or questions.

If this technique helps the student to be motivated, creativity will arise as some authors like Ken Robinson states. If the student is doing something that motivates him, he will be susceptible to be more creative on his work [13], and this is more likely to appear in those classes than in a simple power point one.

1.3. Evaluating creativity

There are several methods created to evaluate creativity. One of the firsts was the Torrance Test of Creative Thinking (TTCT), [14], where a series of divergent thinking tasks are given to the student. These tasks are usually open or multi-answer questions. All the answers are correct, however, they were evaluated by experts that determinate if the answers were more or less creative.

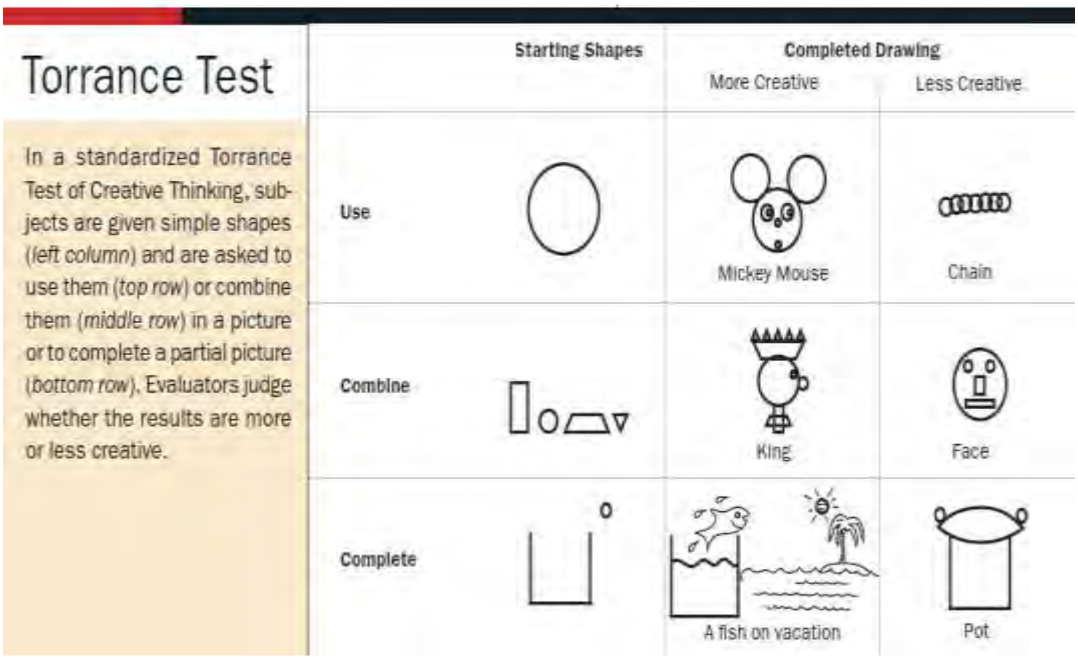

Fig 1. Example of Torrance Test of creative thinking [14]

As an example, a common exercise is the "unusual uses task". In this exercise, the students are required to think of possible uses for a quotidian object others than its regular use. If those uses were new, diverse and complicated the qualification would be higher. Another example is the "histories task", where a specific situation is described and the students have to guess what are the prior events that have provoked this situation.

The TTCT evolved in the Consensual Assessment Technique (CAT) [15], where the experts judge the creativity skill based on their own conception of creativity. The subjectivity of this tests is always controversial, and some authors do not recommend this kind of tests basing its statements in statistical confidence indicators.

Another common method of evaluating a person's creativity is a personal interview with a personality test. After the interview creativity can be inferred from other aspects of his/her personality, [16], [17].

In comparison with the "expert evaluator" methods, there are others that are apparently more objective. These methods use indicators, which do not need an expert to be applied and that reduce subjectivity to minimum. These parameters are called Fluency, Flexibility and Originality. These parameters are related to multi-answer tasks and for this reason, Table 1 will be used as an example. A definition of these parameters is shown below:

- Fluency: The fluency is defined as the total number of responses provided, and it is related to the creativity potential of a person.
- Flexibility: Intuitively, it could be argued that those unusual uses that come from different fields or categories should score better than those that fit in a single topic. For example, making a paper boat and making a paper bird, should have a lower score than making a paper boat and making a fire with the paper. Fluency is therefore defined as the number of categories found in the responses.

  Combining Fluency and Flexibility the "Creative Quotient" is defined. More information about this quotient can be found in [18]. With this quotient, the student A of Table 1 would have a CQ of 5.988 points and the student B 5.311.

  The only trace of subjectivity can be found in the definition of different categories or fields, where a little bit of controversy could appear.

- Originality: If an answer of a student is completely original and is not repeated by any of the students, this answer should score better. The problem with this indicator is that it has a strong dependence on the group. Another problem is that to evaluate this indicator the time and resources needed are excessive.

Student A	Student B
Drawing	Drawing
Making a paper plane	Writing
Burning for heat	Paper for the printer
To dry something	To make a paper plane
As a ruler to draw 90 º lines	To make a paper bird
To make noise	To make a paper boat
-	To level a table
-	To make a ball to throw

Table 1. Example of student´s answers provided in the unusual uses of a piece of paper task.

2. Developing creativity in a Nuclear Engineering Course

As stated before, to develop creativity in the classroom, a creative way of teaching could be used [12]. In this sense, in the nuclear power plants subject the following techniques were used:

- **Role-Play activity 1**: This activity was developed in the radio waste management topic. The class started with a 15 minutes explanation of the main solutions to the nuclear waste management (deep geological repository, transmutation, etc.). After the theory introduction, the students were separated into groups of five to seven persons. Every group was given a different radio waste management final solution. The group had then 30 minutes to create a line of argument for defending their solution against the others. Even if the solution assigned is not the preferred by the students they are told to think as a strong supporter of it. The students are asked to focus on the strengths of their solution rather than the weaknesses of their colleague's solutions and to pretend that they will have to sell their solution to a big company board of directors. This is made to avoid informal speeches and to provide a different environment to the students.

  After 30 minutes each group has to choose a spokesman, that has to make a small presentation of 5 minutes in front of the class defending their solution. They should use a formal tone in their presentation.

  After the presentation all other groups are requested to make questions as a board of directors could make.

  After the questions made by the other students the teacher can make questions and after that, he will provide some feedback to the spokesman. The feedback will include advices related to the oral expression and body language, and to the content of the presentation. This last part will include information about how to explain certain kind of information, how to deal with strengths and weaknesses in the project and how to organize the presentation itself when there is a time limitation.

- **Role-Play activity 2**: The students are asked to make groups of 3-4 persons, and they have to study a specific type of Gen III/IV nuclear reactor to be installed in Spain in the next years against others. The reactor type is assigned by the teacher to each group. The students have several weeks to prepare the written report and the presentation about their type reactor to defend it in front of the class. The presentation lasts between 10 and 15 minutes long and all the members of the group have to explain a certain part requested by the teacher.

As the first activity, the students are requested to act like they are presenting their design to a board of directors of an electrical company. After the presentation, questions are made and feedback is provided to the group.

With this activity two goals are achieved; first, the group will learn about the technology and design of a certain type of nuclear reactor. Second, the group will learn on how to present a project to an investor and how to work in group efficiently.

- **Open questions**: During every class the teacher makes open questions related to the topic he is explaining. Even if the students have no idea, they are requested to think for at least 15 -30 seconds in the possible answer. The teacher afterwards asks random students to explain what he or she has thought. All the students are normally rewarded verbally for thinking of a solution, even if this solution is not possible. This is made in order to avoid that only the extrovert students answer in public. There are one or two open questions in an hour class. It is recommendable to ask only a few because this is mentally exigent for the students.

3. Evaluating creativity in a Nuclear Engineering Course

As several authors state, it is difficult to evaluate creativity isolated from other skills such as intelligence or knowledge. Taking this as an advantage, two methods that involve technical contents and creativity scoring have been proposed. One of them has been recently implemented and the other method has not been implemented yet due to lack of resources.

The first method employed to evaluate a combination of creativity and knowledge is a technical question that appears in the final exam. In this question, the students are requested to predict the nuclear power plant behaviour after an accident that has not been explained in previous lessons. The students have to connect knowledge from several parts of the content and combine them to create a possible solution. As Bloom taxonomy stated [19], the creation or synthesis is a deep state of knowledge. Creating this solution implies the use of creativity skills and therefore these are evaluated. The students had a very good response to this question, stating that it increase their motivation for the study.

The second method is still under review and has not been implemented. It consists of a combination of a "histories task" with technical content. The students are given a certain state of a nuclear power plant, and then they have to guess what happened before, that has lead to this situation. This question will be evaluated with the parameters Fluency, Flexibility and Originality. An example with possible answers of a student is given below.

Example Question: *A Safety Relief Valve of the pressurizer is open, what are the possible causes for this situation? Try to be creative*.

Student Answers:

- Hypothesis A: The plant is under a SBO situation and the pressure has to be decreased
- Hypothesis B: The plant is stopped because is on recharge and there are maintenance duty being carried on.
- Hypothesis C: The plant is under an SGTR situation and the valve has been opened manually
- Hypothesis D: This is an spurious opening of the valve
- Hypothesis E: The plant has been taken by terrorists that plan to melt the core.
- Hypothesis F: The plant is in a LOCA situation.

Hypothesis F, unless given more information will be a wrong answer. The rest can lay in three categories, accidents, maintenance, and external human events.

With this type of open questions, creativity can be objectively evaluated. Moreover, if the students lack of technical content, they will not be able to use their creativity.

4 Conclusions

Creativity is a desirable skill in engineers for companies or institutions. Even though creativity is hard to define, evaluate or develop there are some modern techniques to do it. Therefore, Technical University of Madrid is carrying out initiatives to develop creativity on its students. To develop creativity, three main activities have been made, that are not disconnected from the technical content. This activities make the students learn the technical contents in a creative way. This is an appropriate way of developing creativity according to some authors. Role-play activities were made, as well as open questions to the class that invite the students to reflex. The students were enthusiastic about this teaching method, very different from other subjects, increasing their motivation in learning.

After creativity is developed, it is evaluated. Evaluating creativity isolated from other skills is not possible, and in our favour, the scoring is a mix of creativity and technical knowledge. A question about a NPP accident that has never been explained in class is part of the final exam. The students have to connect knowledge from many parts of the content, and if they are able, that implies that the learning is good and deep. The students have a very good opinion of this question, stating that it helps their study motivation.

Students, in general have a very good opinion of this initiatives that have been carried out last year. Creativity has now become a trend that has to be taken seriously into account for the future engineers as well as the future companies.

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PLAY AND LEARN – A SERIOUS GAME FOR A BETTER UNDERSTANDING OF SEVERE ACCIDENTS

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ABSTRACT

A big challenge for nuclear science professors is to teach accidents in a correct and systemic way. Of course, we currently have a lot of technical details and scientific data about the progress of severe accidents as TMI or Chernobyl. So, an “a posteriori” analysis is quite easy, with a chronological description of the events and the plant evolution. But how to explain the operators’ confusion, the ambiguity of messages, timing aspects and so on… Students usually say “Why didn’t the operators do this or that?”, “Why didn’t they correctly understand what was happening?”…

Hopefully, the “Sprintfield power plant” exists! This plant is purely virtual and can explode without any damages. This is what it is called a “serious game”. It is a very simplified but realistic simulation based on a true story: the Three Mile Island accident. Students are divided into groups of 4 members; each of them has a specific role: primary circuit operator, secondary circuit operator, exploitation manager and safety engineer. Each of them has a “character sheet” that gives specifications and instructions about his (her) specific role. Then the simulation starts: the plant encounters an incident and enters an abnormal situation. How will the team react? How will they organize themselves? What are their priorities? Will they have conflicts? Will they understand the situation? Will they remark that the plant evolves in a dangerous way? How will they deal with conflicting messages? Or incomplete and ambiguous data? How will they react and manage their stress (due to a limited time for decisions)? …

This serious game is an opportunity for the students to experiment a disturbed situation similar in main aspects to the TMI accident and to undergo the same kind of feelings as the operators team did. It is also the opportunity for teachers and students to go beyond simple explanations of accidents, and to understand the importance of human and organizational factors of safety, besides technical ones.

This paper will describe the main aspects and contributions of the Sprintfield simulation. It will underline the way it can be used to improve the training of future nuclear engineers, through the consideration of human and organizational factors and their impact on a team’s ability to manage a crisis situation.

1. Introduction

1.1 Motivations

ISIB (Institut Supérieur Industriel de Bruxelles) is the engineering department of the Paul-Henri Spaak High School, located in Brussels. This department trains students with various specialization: chemistry, physics and nuclear sciences, mechanics, electricity, computer science and electronics. The proposed training consists of 5 years of lectures, laboratories, projects and internships. A multidisciplinary approach has been chosen, with a large place to practical activities. Lectures mainly concerns technical and scientific aspects. Soft skills are slightly and gradually introduced during the cursus.
Nuclear orientation offers a large view about ionizing radiations, their specificities, properties and applications: dosimetry, natural radioactivity, medical imaging… and nuclear power plants. The nuclear energy training spreads over the last two years of the five years cursus. The first part lessons concern normal operation of PWR (Pressurized Water Reactors) while the second part is dedicated to abnormal situations, including safety studies, postulated accidents and actual occurred severe accidents (as Chernobyl, Three Mile Island or Fukushima).

Teaching neutron science is quite easy with classical methods as ex-cathedra presentations. Indeed, we mainly need to describe interactions between neutrons and fuel, structures or other materials and to study their consequences on the core temperature. Then, everything is converted into equations that have to be solved (under some assumptions and with several methods).
But it is very difficult for the students to really understand the complexity of actual severe accidents. Let's have, for example, the Three Mile Island accident. Scientifics and experts have studied this accident and we now have a large number of reports explaining what happened at each seconds and identifying the main issues, problems or errors [1-4].
While presenting this chronological description of the accidental sequence, students do not understand the specific context of the accident, the stress due to the abnormal situation, the lack of information or conflicting data. The first and more common reactions of students usually consist in saying: “Why didn’t the operators do this or that?”, “Why didn’t they correctly understand what was happening?”, “Why did they didn’t diagnose the situation in a correct way?”, or even “How could they make this stupid error?”…

This issue has been solved by the Sprintfield nuclear power plant. “Sprintfield” is a n innovative pedagogical device, developed by Ecole des Mines de Nantes and based on a twofold approach: the simulation of a real complex system and role-play games (RPG). The goal of this device is to place the players, within a team, in a disturbed situation in order to make them experience and understand the difficulties met by team workers, both at the individual and collective levels. The learning purpose is not technical: this device is designed in order to enhance the understanding of the influence of the human and organizational factors, in abnormal situation, on the capacity to control system evolutions and to make collective decisions to go back to “normal” situation.

The joint experiment presented in this paper has been performed as part of the cursus of students from a French engineering school (Ecole des Mines de Nantes) on one side and, on the other side, from the nuclear orientation of a Belgian engineering school (ISIB). This special experiment was a very interesting opportunity to mix students with different but complementary skills: risk management on one side and nuclear engineering on the other side.

1.2 Context of the educational experiment

The experiment described in the following is the result of a dual issue. The first issue has been described in the previous section. The second one concerns the need to underline the

influence of human factors in crises management. Indeed, even if recognized as very important, this influence is also very difficult to explain in a theoretical way, especially when it is decontextualized. Hence, an experiential learning seems to be an appropriate solution.
This experiment is also the result of collaboration between two European universities.
The first one is a French university: Ecole des Mines de Nantes. It trains “no-specialist” engineers and attaches a great importance to human sciences and social sciences. Courses on safety and on organizational and human factors (OHF) take place during the cursus because, throughout their careers, engineers may have to work in a risky professional environment. Nevertheless, the risk perception of students is generally influenced by preconceived ideas and misrepresentations, amplified by some media messages. Hence, in order to correctly deal with risk management, it is important to modify this perception and to clarify the preconceptions laying in the student minds.
The second one is a Belgian university: Institut Supérieur Industriel de Bruxelles (ISIB), a department of the Haute Ecole Paul-Henri Spaak (as described in the first section).

This experiment took place for the first time in the cursus of Belgian students in Nuclear Engineering, during the fifth and last year, at Ecole des Mines de Nantes, with French Students. These Belgian students have technical and scientific knowledge about nuclear power plants, in various fields: neutron science, thermal-hydraulic science and safety studies. They also learned the main postulated accidents for PWR (Pressurized Water Reactor) as Loss of Coolant Accident (LOCA), steam generator tube rupture accident or steam pipe failure accident and the analyses of some actual accidents in the framework of the safety module.

2. Sprintfield serious game

2.1 Sprintfield’s purposes

In order to meet the challenge of teaching the complexity of crisis management and the impact of human factor, the best educational methods are “living methods”, methods where students are involved, included and acting.

The limits of the ex-cathedra lectures are well known and the amount of acquired knowledge decreases dramatically over time.
Case analysis are often used to solve this issue but the knowledge acquisition is still limited [5]. Students imagine with hardness difficulties and constraints linked to the studied case. They do not have any experience of risky professional situations. Moreover, they did not develop any feeling of responsibility related to risk management.
Both simulations and role-play games force students to take an active attitude in their learning [5], [6] and [7]. Nevertheless, role-play games (RPG) confront students to real issue and force them to act; they feel the situation instead of just thinking of them. Students are involved in the game evolution and, consequently, are highly involved in the learning process.

“Sprintfield” is an innovative project initiated and designed by teachers from Ecole des Mines de Nantes aimed at making students more involved in risk management and was based on two pedagogical assumptions: the acquisition of HOF theories is facilitated by experiment and the fact of living complex situations helps developing intra- and inter-personal competences.
“Sprintfield” is an active method where students live a degraded professional situation. The retained context is a real and well-documented accident occurred in a nuclear power plant. Each player has a specific role with specific objectives and specific information. In respect with creation rules of RPG, instructions are very general and differ from a player to another [8] and the game evolves according to random events or to actions and decisions from players [9]. However, players have to work together in order to save the nuclear power plants. Consequently, they have to organize themselves, to define a way of work and to

communicate in an efficient way. This role-play game have the form of a computing interface with a limited number of data and possible actions.

At the end of the game, a two-phases debriefing is organized. The first one takes place immediately after the game, without real time for reflection. The second one takes place weeks later, students have time to analyse what they lived and the way they react. During these debriefing, students also have to explain (or try to explain) their behaviour and decisions. Which elements do influence the decisions? What is at the origin of these disturbing elements? They have to justify what they did. It allows to make them aware to their responsibilities.

2.2 The game progress

The game is divided into three phases, with specific tasks for the players: the initial phase, the simulation phase and the feedback phase.

The initial phase

The game starts with a short presentation of the experiment. Teachers explain the context of the scenario: participants are operators in a nuclear power plant, it is night shift, the technical team is reduced (only one available technician) and, at the morning, they will have to hand over to the daily team and to expose the plant situation.

When the situation is well understood by every participant, the teams are randomly generated and the roles are randomly distributed. (In our particular case, attention has been paid in order to have specialists and no-specialist in each team.)
The teams are distributed in the room and each participant receive a badge with his role, a general document about the nuclear power plant (descriptions, schemas …) and a specific document explaining his role (objectives, legal responsibilities, place in the hierarchy, rights and duties…). Students start reading the documents… There is no timing limitation, students start the next phase as soon as they have understood the context of the game and their role.

The simulation phase

When students are ready, they start the software.
First, participants discover a short description of the graphic interface, the way to interact with the technician, the different indicators and the order panel. Then, the simulation really start…

After each warning message, participants have a specific timeframe to do something or to decide not to do anything. This timeframe is indicated on the screen by a red countdown. Sometimes, there are many warnings within short timeframe and, sometimes, nothing happens during several minutes.
The technician gives information about the status of system and sometimes proposes actions to perform. The participants can only say to this technician to perform the action or not; it is not possible to ask the technician to do something else or to ask for a data.

The game finishes when a safe situation is recovered or when the accident is reported to the authorities.

The feedback phase

During the simulation phase, players lived a stressful situation. Thus they need a break, at the end of the simulation phase, to chill out and to release the accumulated pressure.

After this break, each team has to prepare a short presentation about the final state of the nuclear power plant, the succession of events and decisions leading to this state. Indeed, the night is over, the daily team arrives and useful information have to be transmitted.

Finally, each team might determine the level of the INES scale associated to this final state.

3. Analysis of the experiment course

3.1 Teachers point of view

As soon as the game starts, players are alone. They may not ask for help or interact with other teams or teachers, they have to act on the basis of their knowledge and documents.

Nevertheless, teachers do not actually disappear, they observe the behaviour of each team… Indeed, even if the starting point is the same for everybody, the teams' behaviour quickly differs: the attitude of the students during the documents reading (annotating, highlighting, making notes, just reading…), the relative position of the players and the computers (accessible for everybody, close to the operators, close to the computer's owner…), the use of the badges (with the specific role of each player)…

The role appropriation and the communication within participants of a team also vary. In some teams, there is almost no discussion, one participant is in front of the computer and the others participants focus their attention on their own papers and scarcely look to the screen. In other teams, the discussion is very important and the decisions are the fruits of actual consensus. These teams erase the specific roles and each player operates in the same way. In other teams, the roles are taken seriously and conflicts may even emerge, according to the character of the gamers.

During the initial phase, students are warned that they will have to perform a quick feedback to daily teams. So, during the simulation phase, some students note approximatively everything but most of them are completely immerged in the simulation and completely forget this feedback.

Another part of this experiment is the participation of "nuclear specialists" and "no-specialists". The game has been developed in order to be accessible to uninitiated students; no technical knowledge is needed to play. Nevertheless, initiated students use their scientific background and have a slightly different vision of the accident course. Each team of the experiment was composed with initiated and uninitiated students. This combination led – in each team – to the transmission of technical data and improved the discussions in qualitative and quantitative ways. The result was mainly a good collaboration between participants with respect of each other.

3.2 Students point of view

At the end of this game, students were happy and realized they learned a lot in a funny way, they had the unique opportunity to live a disturbed situation in a nuclear power plant and to feel the difficulties as the TMI team did.

Moreover, players mainly highlighted the following aspects. The first action during the simulation is a "reflex" action and could dramatically change the safety level of the nuclear power plant. Students also experimented the impact of the stress (mainly due to the flashing countdown) on reflections and reactions or on discussions between team members. Neither the hierarchy level nor the legal responsibility of some roles did actually affect the experiment course.

4. The experiment exploitation

The following of the associated academic modules uses this experience to develop the study of human factors and their impact on the evolving of a perturbed situation.
For the Belgian students, this experiment and the associated living have been used in two different ways.

The first one was the main purpose of the Sprintfield serious game creation: studying the human factor in crisis management. First, the teacher debriefed this experiment while comparing the behaviour of each team during the game and showing pictures taken during the game. Students were very surprised to discover how different their attitudes and reactions to a same situation were. It also was the starting point to discussion about no-verbal communication. As second stage, teams received the technical description of their nuclear power plant evolution and the choices they made. On this basis, each team had to present a detailed feedback of the experiment. The Belgian students mainly focused on technical data and noted messages' ambiguities, misunderstanding of the actual plant situation or inconsistences of their decisions.

The second way was more inconspicuous… Students lived this experiment without knowing that its scenarios is based on a true story: the Three Mile Island Accident. The safety module part dedicated to occurred accidents was deliberately left for the end of the module in order that it will start after the Sprintfield experiment. When the TMI accident description arrived, students were more mindful as the previous years and they realized that it was the same situation as what they lived a few weeks before. Their interest was boosted up because this description left a purely academic explanation and theoretical description, it became real. Consequently, the comprehension of this accident was improved, mainly on the human aspect and on the reaction of operators to conflicting information, lack of correct data…

5. Conclusions and perspectives

"Sprintfield" is a powerful pedagogical device to introduce the specificities of disturbed situations [10] as severe accident in nuclear power plants. It highlights the impact of human factor, the roots of some « mistakes » and their consequences.

The main purpose of "Sprintfield" is really not to improve or check the nuclear knowledge of the students but to emphasize the human and organizational factors. Consequently, "Sprintfield" is willingly a simplified interface based on a simplified scenario. So that, no-specialist students understand the basis of the nuclear power plant operation thanks to simple and clear documents. However, "Sprintfield" is also used with specialist students. Hence, it should be realistic enough and sufficiently conform to physics and reality to stay credible for students aware with nuclear technologies. So that, specialist students, familiar with these basic notions, may apply their knowledge and speculate on the consequences of the proposed actions. Sprintfield meets this dual challenge!

Nevertheless, Sprintfield is a kind of prototype and could be further developed. The main improvements concern the interface quality (by increasing the interactivity), the beginning of the scenario (by adding a previous phase with a few actions to perform before entering the disturbed situation in order to increase the roles appropriation) or a diversification of the scenarios.

In brief, Sprintfield is useful both for specialist and no-specialist students and focus on human factor. It still could be improved and could require the use of nuclear knowledges for specialist students.

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INNOVATING NUCLEAR ENGINEERING EDUCATION AND TRAINING THROUGH OPEN AND ONLINE CULTURE

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ABSTRACT

In the nuclear sector new approaches in Education, Training and Information (ETI) activities are being demanded to enhance important aspects as communication, motivation, effectiveness, project management or capacity building in the involved organizations. Our multidisciplinary team of experts has been working in different fields, all of them related to the design and implementation of innovation actions in nuclear education, which we will present in this contribution.

On one side, we have concentrated our effort in applying innovative tools and methodologies of online education in nuclear engineering. In this direction Massive Online Open Courses (MOOCs) and Open Course Ware (OCW) play an important role. These options could be very helpful for dissemination activities in nuclear engineering. We think that the extended phobia towards nuclear has a lot to do with a lack of information to society as well as the many times incorrect messages sent by the media. A MOOC on Nuclear Safety Culture within ANNETTE H2020 project and an OCW on Fukushima Nuclear Accident to be transformed into an informative and basic MOOC are the first subjects to work on.

Regarding the difficulty to find appropriate open educational resources in nuclear engineering for a particular educational need, we are also working on the possibility to introduce data mining techniques and semantic web in order to automatically generate a useful indexed database.

One of our worries is the scarcity of postgraduate specialized nuclear engineering education in an international level. Face-to-face education is very difficult and expensive to achieve in this field, and distance and blended education can overcome this difficulty. We started with the production of a fully online course on a very specific topic for postgraduate students within ENEN III, a project of the 7th Framework Program. Lessons learned with this experience led us to adapt the educational material, and to the path to the actual situation.

Another field we have taken into account is Nuclear Knowledge Management (NKM), so closely connected to Nuclear Safety Culture. NKM represents a new strategic tool in business to improve the knowledge assets within an organization and to preserve nuclear knowledge. To that end our participation in KEEP Group (Knowledge Exchange, Elicitation and Preservation), recently created within the Spanish nuclear fission technology platform CEIDEN in order to work on NKM enhancement has driven the design and implementation of an UNED university lifelong learning online course on NKM in Spanish starting in January 2016, in collaboration with ICA2 Innovación y Tecnología, aimed at professionals who want to implement or improve this methodology in their organizations.

Lastly we are also doing work on educational methodologies, developing a methodology to record videos for computer science MOOCs that we plan to adapt to the nuclear engineering MOOCs to be developed.

In order to answer these challenges, UNED expertise in distance education, blended and online learning and in Open Educational Resources (OER), the expertise in Engineering Education Innovation, as well as that of ICA2 Innovación y Tecnología

in Innovation and Knowledge Management represents our background for a multidisciplinary approach to the development of the different proposals our group is carrying on.

1. Introduction

1.1 Our approach in the context of nuclear education

Nuclear accidents have a great impact in public opinion, but information by the media is usually biased and rarely accurate. The need of a highly effective communication, mainly in issues concerning nuclear safety culture, demands a new approach in education, training and information (ETI) activities. New tools and methodologies could have an important role to tackle this situation, in such a way that the general public were not confused by the nuclear detractor media [1].

Regarding nuclear engineering education the use of options such as Open Course Ware (OCW) and Massive Online Open Courses (MOOCs) could be very helpful for the dissemination in nuclear engineering, especially regarding the extended nuclear phobia in our society. These course formats can be also very attractive for students in locations where universities do not cover this field.

UNED expertise of more than 40 years in distance education, blended and online learning since 2000 and, more recently, OER developments such as OCW and MOOCs, as well as UNED research on quality issues on these topics [2] [3] represents our background for a multidisciplinary approach to the development of the different proposals our group is carrying on to give response to the above challenges.

Thus, our team has been exploring online training and it is designing OER in the nuclear engineering field, implementing MOOCs on Fukushima Accident and on nuclear safety culture, as well as developing a classified database of nuclear engineering resources. The Nuclear Safety Culture MOOC will be developed within Horizon 2020 (European Commission) project ANNETTE (Advanced Networking for Nuclear Education and Training and Transfer of Expertise) [4] [5], a proposal led by the European Nuclear Education Network (ENEN).

On the other hand, nuclear stakeholders are increasingly interested in implementing good knowledge management culture. The International Atomic Energy Agency (IAEA) has already stated the need to preserve nuclear knowledge and has created the Nuclear Knowledge Management unit (NKM), responsible for its dissemination worldwide [6].

NKM organizational processes, so closely linked with nuclear safety culture, are essential to address the previously posed problems, and represent a new strategic tool in the business environment, therefore improving the knowledge assets of an organization.

In Spain, KEEP Group (Knowledge Exchange, Elicitation and Preservation) has been recently created within the national nuclear fission technology platform CEIDEN [7], in charge of studying the Spanish situation regarding NKM. In this framework, KEEP members, UNED and ICA2 Innovation and Technology have proposed to create an online course aimed at professionals who want to implement or improve this new methodology in their organisations. So far, there is not a course in Spain suiting these needs, also very useful for other Spanish speaking countries.

1.2 Early approaches to online courses and MOOCs: a pilot experience in online international nuclear engineering education, its redesign into a MOOC and the development of a new MOOC within FP7 NUSHARE project

Our team began to face these challenges with the production of a fully online international course for postgraduate students on "Accelerator-Driven Systems (ADS) for advanced nuclear waste transmutation" [8], addressing a new nuclear reactor design that may improve nuclear waste management. Nuclear transmutation is a hot research topic with a much-demanded benefit for society: the decrease of the volume and radiotoxicity of the high level radioactive waste generated in the nuclear power plants [9]. Although it is a subject unknown for the general public, it is a priority in the current research initiatives. Based on the previous research collaboration between the Power Engineering Department of UNED and CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas), we developed a pilot online course within ENEN III, a FP7 project (7th Framework Program), led by ENEN [10].

In order to address the lack of this kind of specific international courses in nuclear engineering subjects, we thought about the opportunity of redesigning the pilot course on ADS systems into a X-MOOC type, that is, a type of MOOC designed in a similar way to more formal online structured course, making use of video presentations, documents, forums, short quizzes and online testing although not being formally tutorized such as in the pilot course. To design this MOOC, we could then benefit from all the course materials and the lessons learned from the previous pilot online course [11].

Following the previous pilot course and its redesign into a MOOC, we decided to investigate deeply in the field of MOOCs for Nuclear Engineering and made a MOOC proposal within NUSHARE project. NUSHARE is a FP7 project implementing a European Education, Training and Information initiative proposed by the Commissioner for Research and Innovation and the Commissioner for Energy after the Great East Japan Earthquake and Tsunami on Fukushima. The focus of this project is to enhance safety culture in all types of nuclear activities including security applications.

Within NUSHARE Project we proposed the design and implementation of MOOCs for the medical sector [12]. Safety culture in the use of radiation techniques is specially needed for medical doctors prescribing irradiation techniques for diagnosis or treatment and also in case of a radiological emergency. This proposal was very well received in its presentation in “NUSHARE Stakeholders’ Meeting” in 2014, but it could not be implemented because of the lack of funding. Nevertheless, we were told it would be considered for future phases of the project.

Based on these previous experiences, we are currently working in open online courses and new tools and methodologies for innovation in nuclear engineering education, with the following guidelines:

2. Actual guidelines

Our team is now facing different but related challenges under the following guidelines, as explained below (see Fig.1)

2.1 Production of a specialized MOOC in a European project within H2020 led by ENEN: ANNETTE

The actions of the project intend to contribute in reinforcing the Europe-wide cooperation in the nuclear field, by proposing courses and different initiatives on Nuclear Safety Culture (NSC) for different target groups. The aim of these courses is to strengthen the required competences for achieving excellence in Nuclear Safety Culture. These courses will be mostly offered in the frame of the advanced European Program.

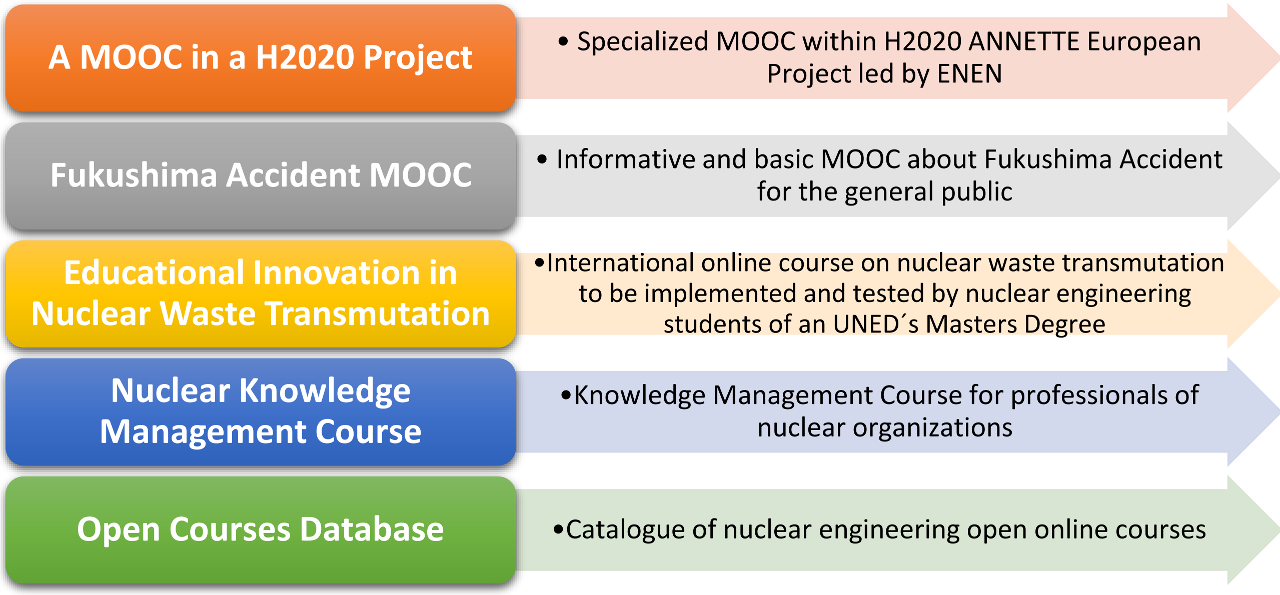

Fig 1. Guidelines

In this framework, UNED proposal consists on the production of a specialized modular MOOC focused on Nuclear Safety Culture, with a workload of 1 ECTS. Course materials will be elaborated in collaboration with TECNATOM, the first Spanish training provider in the nuclear sector.

In ANNETTE project, UNED contribution refers to its support on the development of X-MOOC methodology, covering the following aspects:

1. An appropriated virtual learning platform, including hosting, course delivery and facilitators.

2. Course General Design and methodological and quality issues required for the implementation of the MOOCs.

3. Staff training: course experts, facilitators and curators.

4. MOOC contents generation by module. UNED will provide its own professional studio for video classes recording and a specific guidance on the development of each module materials as video lectures, quizzes, peer-to-peer activities, final evaluation design, customized surveys, etc.

5. Course dissemination advice.

2.2 A dissemination course about Fukushima Dai-ichi accident in OCW and MOOC versions.

There is a large amount of information about the Fukushima accident in the Internet, available in many different languages, but we have not found any complete structured information in English or Spanish with pedagogical goals. In this context, OER options may be a useful approach to be explored. Thus, a dissemination course is proposed. Design and materials will be suitable for both a first OCW course and an X-MOOC.

Goal

The objective of this course is to provide relevant information about the accident to the general public, explaining each event, the international reaction as well as the lessons learned. Any person could take the Fukushima Accident course, since it does not have any specific requirement. Also, additional materials will be available for any student with a technical or specialized background in order to make the course more interesting for them.

The course will be multiplatform (web and mobile devices) allowing the users to better understand the contents in an easy, flexible and friendly way, regardless of their educational and technical background and, thus, achieve an objective, precise and reliable perspective of the events that shocked people over the entire world that day.

Main contents

The Fukushima Accident open course will be structured in 6 learning units, see table 1.

Unit	Content
1	*Nuclear Energy. Nuclear Plants:* Nuclear energy. The nuclear fission and fusion. Nuclear Power Plants. BWR reactors.
2	*Accident precursors:* Fukushima Dai-ichi nuclear power plant. Safety systems. The earthquake. The Tsunami.
3	*The nuclear accident:* What is a nuclear accident and which are the most relevant. Timeline of the accident. Comparison with Chernobyl and Three Mile Island.
4	*Radiological impact and radiological protection measures:* Radioactivity basics. Effects of radiation in humans. Consequences of the accident. Existing protecting measures.
5	*Impact of the accident and measures taken:* International reaction. Stress Tests in Europe. Situation in Spain after the accident.
6	*Lessons learned:* Conclusions and measures taken both in Japan and internationally after the accident.

Tab 1. Learning units of Fukushima Dai-ichi Accident open course

Testing the contents by nuclear engineering students

In order to test the open course, a pilot experience will be first offered to students taking the subject “Fundamentos de Ingeniería Nuclear” (Nuclear Engineering Basics), taught by UNED Power Engineering Department in the Degree of Industrial Engineering. Students who successfully participate will earn 1.5 ECTS elective credits. An additional objective of this methodology is the development of core competencies for future graduates, both with regard to the mastery of contents of the subject, on the one hand, and generic competencies related to information management and communication as well as teamwork skills based on collaborative activities, on the other hand. Students’ motivation and engagement are expected to increase with this activity, and thus a better assimilation of the university subject.

This experience will include learning activities based on cooperative approaches introducing "peer learning". Students’ evaluation will be mainly based on new contents generated by them in team-working activities. This production should be based on the adequate study of the contents and activities of the open course. Therefore, this methodological strategy will allow to test the content of the OCW course and also to generate new materials, created through collaborative work. New contents could also be incorporated to the open course materials in future editions.

Obtaining relevant information on the effectiveness and feasibility of the method will allow us to learn from the experience and to improve our proposals. We plan to include as far as possible learning analytics through surveys and other learning monitoring.

2.3 A pilot international online course on nuclear waste transmutation to be implemented and tested on a subject of UNED´s Master in Industrial Engineering

This project is the evolution of the international pilot online course on ADS for waste transmutation developed within FP7 ENEN III, which also was redesigned into a MOOC, as explained in heading 1.2.

The content of this pilot course covers a syllabus section of a 5 ECTS subject in UNED´s Master in Industrial Engineering: "Tecnologías para la Gestión de Residuos Radiactivos" (Radioactive waste management technologies). The students of this subject who voluntarily participate with success in this project will obtain 1.5 ECTS.

Goal

The main objective is to test the pilot online course in a University related subject, as well as to improve the course evaluation methodologies to assess this experience.

In addition, students will acquire generic competencies, such as reading scientific papers in the field in English or developing communication and teamwork abilities.

The implementation of this material within the Master´s subject will be evaluated to become part of the compulsory material.

Methodology

The main learning material of the course consists of seven modules, with a 30 min video-classes each, and presentations. In addition, Mathematica simulations with explained audio will be provided. These materials were elaborated by Enrique González, Head of the Nuclear Fission Division, CIEMAT.

The tutoring activities of the course will be carried out through chats and forums. Mandatory web-conferencing will be used to evaluate the acquisition of the learning outcomes.

Course activities

The following Table 2 shows the student activities

Activities	Duration
Watching videos and studying their PowerPoint presentations	15 hours
Studying additional materials	10 hours
Studying simulations and doing simulation tasks	5 hours
Forum participation	2 hours
Web conferencing assistance	4 hours
Final exam	1 hour

Tab 2. Course Activities within the Industrial Engineering Master subject

Evaluation

The final success of the participation will be achieved by the adequate completion of a final online exam and by the active participation in the course, especially in web-conferencing.

2.4 Online course on nuclear knowledge management for nuclear organizations.

Another line of action we are working on in the nuclear engineering field is the development of an innovative online Knowledge Management course, in agreement with the objectives of KEEP Group of CEIDEN Platform, under a lifelong learning perspective.

The loss of institutional memory in governments, organizations and research institutes, the aging of many professionals in the nuclear power plants and the shortage of a new generation of professionals, can pose difficulties in the preservation of the actual nuclear programs [13]. Regarding this situation, the main objective of knowledge management is to improve communication and the transfer of knowledge and accumulated experience in nuclear technologies by trained personnel, addressing the complexity of the regulation and the internal data processing in this sector.

We also come up with the difficulty of lifelong learning with scarce, expensive and hard to attend face-to-face courses in the nuclear sector. For this reason, we propose an online approach that could give answer to these new challenges.

Goal

The general goal of this course is the development of knowledge management skills, in the context of the organizations of the nuclear sector.

The target group of the course are professionals from the nuclear organisations interested in organizational issues and, mainly, those ones of this sector who require flexible continuing education. For this reason, we consider e-Learning as a very appropriate educational method to cope with these new demands.

Features

The Knowledge Management course for nuclear organizations took place from January 18th 2016 till May 13th 2016. Enrolment was available through UNED "Formación Permanente" website as a university-lifelong learning course.

Course Design, methodology and contents

The course is structured in four modules, each lasting three weeks, and an extra week for those students not able to complete the activities in the previous week.

The course is delivered in UNED aLF virtual learning platform (based on DotLearn open platform). Online tutoring is developed through synchronous and asynchronous communication tools (chats and forums). All multimedia materials, specifically developed for the purposes of the course, are available in the platform.

Main contents and learning outcomes are described in Table 3.

Learning materials

The learning materials are lectures and exercises specifically made for this course by UNED Power Engineering Department and ICA2 Innovation and Technology. ICA2 has a wide experience in this field as consultants offering their services of knowledge management in the nuclear sector organizations [14] as well as other companies in the energy sector.

There are also introductory videos for each module and interview videos with relevant people in nuclear knowledge management talking about their own experience.

Each module includes links to external bibliography as optional additional material, where students may have further readings about the different topics of the course.

Learning activities and Evaluation

The active participation in the learning process via the forums is key in the course, as well as the exercise of transferring the learning initiatives that may be implemented within the organisations of each participant.

Module	Learning outcomes
I. The value of knowledge in the organizations of the nuclear sector	To know and to understand the value of knowledge within the nuclear sector through an explanation of hints, trends and significant events that have influenced the importance of knowledge management
II. Intangible assets: Intellectual capital in the organizations of the nuclear sector	To understand the essence of intellectual capital and the structure that allow the identification and measurement of intangible assets that add value to organizations. This structure concerns human, structural and relational capital issues.
III. Knowledge Management model and strategies for organizations of the nuclear sector	To know four major orientations from the capture, dissemination, assimilation and application of knowledge and based on sorting criteria, socialization, connection and development of knowledge within the nuclear sector.
IV. Competencies for Knowledge Management	To identify professional profiles in organizations to propose an adequate management model: units, committees, posts, etc., as they already exist within the nuclear sector

Tab 3. Body and content of the *Knowledge Management Course for nuclear organizations*.

2.5 Open database with the main available online open nuclear engineering educational resources

A the time of assessing the interest of redesigning the pilot course on ADS Systems (described in 1.2) to be evolved into a MOOC, our group did a previous search in which we analysed the current situation of OER in nuclear engineering. This search showed the scarcity of nuclear engineering open online courses. The large amount of OER available in Internet, usually dispersed and without a course design, can overwhelm and confuse people interested in learning about nuclear engineering in a more structured way.

The goal of this project is to create a comprehensive, classified and labelled database including all nuclear online open courses worldwide in English language, providing guidance for interested public.

The starting point of this database is the results of our previous search. We have also considered the extensive IAEA database, very relevant for bibliographic searches. New methodologies, like Data Mining, are being evaluated to elaborate this catalogue in the near future.

The database will contain all the results of an updated, exhaustive and accurate search, classified by metadata designed to assess the main pedagogical issues of interest for learners, for example, the knowledge requirements to follow the course, or the learning methodology applied. In addition, it could be an interesting tool to analyse gaps in nuclear engineering open courses in order to guide the development of future open educational materials.

This database will then be an interesting educational resource and may be a valuable tool to make society more familiar to nuclear engineering related issues.

3. Conclusions and future work

This paper has described a variety of innovative approaches in the nuclear engineering education field that are being developed by our group, taking special advantage of the OER movement applied to this usually closed and restrictive area of knowledge and training:

• The contribution to a new educational approach in nuclear engineering in order to encourage other organizations to shift the traditional paradigm, and to innovate their teaching and learning methodologies, as done in many other knowledge fields, by incorporating online programs and different educational proposals based on the use of OER.

• All these new proposals go in the direction of reducing ETI activities costs, especially difficult and expensive in the case of some nuclear engineering topics, usually taught in face-to-face sessions. They also allow the growth of dissemination activities among the society.

• Regarding bringing the general public closer to nuclear knowledge, OCW and MOOCs proposals are an excellent option thanks to their massive nature and cost effectiveness, and the flexibility that allows society to make compatible family and work responsibilities with achieving a reliable information and education in nuclear fields.

• These new teaching and learning methodologies are not only making significant contributions for the general public, but also they may become an excellent platform for networking activities to strengthen the links among expert personnel in different topics of study, and to enhance the education and the communication for the creation and co-creation of educational materials.

• These research guidelines encourage an open collaborative spirit. The spirit of listening follows the win-to-win theory. They are an ingredient for the change within the nuclear sector, enhancing the transparency, the communication, the ability to listen to criticism, etc., in order to establish a change in the communication in between stakeholders, and between the general public and the experts. This contributes to enhance nuclear safety culture, which is in the core of the sustainability of nuclear energy and the nuclear sector.

• Connected to these previous opportunities, the innovative concept of co-creation of contents through online collaborative tools, and the experience of nuclear engineering students participating in this kind of proposals, allow presenting the production of new contents as a new educational trend in the field.

• Finally, testing these activities by the students is also a new idea to apply to nuclear engineering education. With the integration of collaborative tools and methodologies as "pilot experiences" within regular courses, a wide search on open educational resources can be done in a reliable and complete way, likely increasing students' motivation and engagement with their studies.

In sum, innovative scenarios applied to education in a specialized, complex and no massive area of knowledge, such as nuclear engineering, are clearly necessary. In this sense, we agree with OPEN UK experts' recent report with the idea that "Social learning is not just a means of sharing learning resources, but a valuable activity in itself. Learning together creates a 'shared mind' that combines different perspectives and alternative ways to solve problems" [15], a relevant issue facing XXI century difficulties and challenges as in the nuclear field.

4. Acknowledgments

We would like to thank Enrique González (CIEMAT) for his talented work on developing learning materials on ADS systems for waste transmutation and his interest in online education for technical nuclear engineering experts, and Ángel Fernández-Luna for his work on MOOCs in nuclear engineering.

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Discover the ‘maze’ of networks

AN AMAZING FIRST TEN YEARS FOR THE NUCLEAR TECHNOLOGY EDUCATION CONSORTIUM

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ABSTRACT

Established in 2005 to meet the growing requirements of a highly skilled workforce for the UK nuclear industry, the Nuclear Technology Education Consortium delivers a unique nuclear Master's programme designed for industry that is taught in a short-course format. It is also available as a one-year course for full-time students, with an increasing number of foreign students. Building on the long-standing nuclear expertise of the partner universities which work together in NTEC in a collaborative way, the consortium also co-operates very closely with industry to ensure that the students graduate not only with a very high skill level but also that the skills are relevant for the demands of industry. This close connection between NTEC and industry has been the key to the success over the first ten years that enables NTEC to be completely self-sustaining with no funding from Government.

Since 2005 there have been dramatic changes in the way we communicate. NTEC has embraced these changes and refined the programme by the provision of many of the modules in a distance learning format with enhanced use of social media, such as Facebook. This ensures that remote students are remote only in their geographical location. The next ten years and beyond will bring many more changes in the nuclear industry, our education systems and ways of communicating, but based on our first ten years of success, NTEC is ideally placed to adapt, grow and maintain both the quality and quantity of students required.

1. Introduction

Nuclear education in the UK at the turn of the century was described as a hospital patient requiring intensive care to [1] ensure that the UK nuclear power plants had the highly skilled workforce required to operate them to 2035 and beyond. Urgent action was required if nuclear education within UK universities was going to be a viable option for students and more importantly support the UK nuclear industry. An audit of existing nuclear courses revealed only two, at the University of Birmingham and at the Defence Academy, that had a majority of nuclear content and that were graduating students that had the skills required by industry.

Overall though, the situation was not as bleak as it may have seemed as there were pockets of nuclear expertise in many universities with some green shoots of growth developing from the four BNFL University Research Alliances (URAs) that had been established from 1999 to 2002. These URAs were established to attract the best chemists, chemical engineers and material scientists to create world-leading research centres in radiochemistry, particle science, immobilisation science and materials performance. Despite some cuts to funding the UK nuclear physics community was still buoyant and managing to maintain the UK's world-class capability. The Defence Academy was also maintaining our nuclear submariner capability. Remedial action for postgraduate nuclear education was therefore needed but achievable to ensure the prolonged operation of the UK's civilian nuclear power plants.

2. The Stakeholder Consultation

The UK electricity industry was privatised in the 1990's with the Central Electricity Generating Board's (CEGB) ownership of the nuclear reactors split according to the reactor type with BNFL taking ownership of the Magnox fleet and British Energy, until the buyout by EDF, ownership of the Advanced Gas Cooled reactors and the UK's only pressurised water reactor. By 2005 with the establishment of the Nuclear Decommissioning Authority (NDA) the landscape had changed again with the NDA establishing completion for the management of the nuclear sites apart from those owned by EDF. Together with the defence contractors such as Rolls-Royce and BAE Systems and major supply chain companies such as Amec, as was, now Amec Foster Wheeler and Cavendish Nuclear there were a number of companies with an inherent interest to recruit highly-qualified nuclear scientists and engineers.

A stakeholder dialogue was therefore conducted to ascertain which subjects should be taught in a Master's programme, as a postgraduate nuclear qualification complementing a generic science or engineering Bachelor's degree was the preferred model, as well as the delivery format to ensure that both full-time and part-time students currently employed by the nuclear industry could attend the courses and Master's degree programme. The choice of courses was also dependent on the expertise then available within the nuclear universities.

A short-course delivery programme was the favoured format for industry enabling the part time students to attend each course on a one week, Monday to Friday basis. This was determined to be less disruptive for the companies. The Nuclear Technology Education Consortium (NTEC) was therefore established in 2005. The university partners that constitute NTEC are not fixed and have changed over the last ten years, the current partners are –

- University of Birmingham;
- University of Central Lancashire;
- Imperial College London;
- University of Leeds;
- University of Liverpool;
- University of Manchester;
- University of Sheffield;
- Defence Academy, College of Management and Technology.

These universities now offer the following twenty modules as the NTEC consortium –

- ***Reactor Physics, Criticality & Design***
- ***Nuclear Fuel Cycle***
- ***Radiation & Radiological Protection***
- ***Decommissioning / Waste / Environmental Management***
- Water Reactor Performance and Safety
- Reactor Materials & Lifetime Behaviour
- ***Nuclear Safety Case Development***
- Particle & Colloid Engineering in the Nuclear Industry
- Policy, Regulation & Licensing
- ***Processing, Storage & Disposal of Nuclear Waste***
- Radiation Shielding
- ***Reactor Thermal Hydraulics***
- ***Criticality Safety Management***
- Risk Management
- Geotechnical Aspects of Radioactive Waste Disposal
- Environmental Impact Assessment
- ***Decommissioning Technology & Robotics***
- Design of Safety Critical Systems

- ***Management of the Decommissioning Process***
- Experimental Reactor Physics

The modules in ***bold italics*** are also available anywhere in the world as eLearning, as well as the traditional lecture based learning, reflecting the growing interest of students to study via the Internet. Students in the UK can choose any combination of lecture-based modules delivered by the host university partner, or eLearning, as the learning outcomes for the two different delivery methods are identical.

NTEC students utilise social media platforms and forums are established by the universities to ensure that the students from overseas are integrated into the programme, and benefit from interaction with their cohort as much as possible

Further details of all the modules are available at the NTEC website www.ntec.ac.uk

3. Sustainable Funding

Crucial to the success of any university programme is sustainable funding, this ensures continual support from the universities and course longevity produces alumni in significant numbers. The alumni are recruited by the nuclear industry that increases the visibility of NTEC and helps to market the programme. When NTEC was initially set-up the Engineering and Physical Sciences Research Council provided a small amount of Government funding to cover the establishment of the course and some student fees and stipends, but this support ended after four years. Some bridging funding was then received from the Nuclear Decommissioning Authority that enabled NTEC to develop a fee structure that ensures its sustainability. Support from the nuclear companies in the UK is now a crucial component of the sustainability model, as the fees for their part-time students enables NTEC to offer full fee-waivers for a number of full-time students each year. This model not only educates the current workforce but also provides a pool of graduates that the nuclear companies can recruit from on an annual basis. Recruitment of the NTEC graduates to the nuclear industry is validation that the students have developed the competencies, skills and attitudes to take their place in the professional workforce.

4. Quality Control

The NTEC programme is currently delivered by eight university partners but only three of them - Liverpool, Manchester and Sheffield - register the students enabling them to qualify with a University of Liverpool, Manchester and Sheffield degree rather than a NTEC degree. The three universities are therefore awarding degrees based on some courses studied and examined at other universities. A rigorous quality control process must therefore be maintained to ensure that all the courses offered are at the same standard of excellence each year and by each university. This process comprises –

- Mandatory completion of student feedback forms;
- Mandatory response to student comments by the course leader;
- Annual analysis of quantitative and qualitative student feedback;
- Peer review of all courses by university staff that are not from the university delivering the course;
- Student attendance at Steering Group meetings;
- Industrial feedback through the External Advisory Board;
- A Governance Board comprising the three Registering Universities.

The Nuclear Programmes Office, based at The University of Manchester, is responsible for the day-to-day running of the NTEC programme and is first contact point for any issues regarding, quality and delivery as well as all other logistical issues such as timetabling, marketing, recruitment and examinations. With regular meetings of the Steering Group, External Advisory Board and Governance Board, the Nuclear Programmes Office is able to quickly identify and resolve any issues with the programme. Figure 1 shows the NTEC management structure.

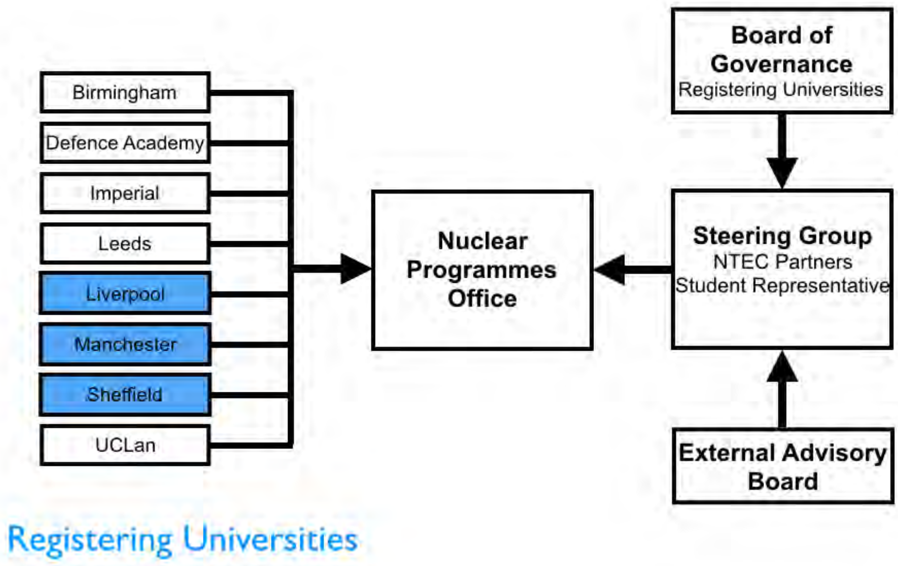

Figure 1: The NTEC Management Structure

5. Industry Partnership

Industry partnership and collaboration continue to be essential ingredients in the success of NTEC as they have been throughout the last ten years. As well as supporting their employees to attend the courses, the UK nuclear industry also supports the NTEC programme by providing an industry location for the Master's projects and industry lecturers provide real case studies demonstrating the theory, techniques and technologies being taught throughout the programme.

The External Advisory Board comprises representatives from industry to maintain the stakeholder dialogue that was started prior to the formal establishment of the NTEC Master's programme. This ensures that NTEC maintains its relevance to any changing demands of industry; this includes the development of new courses if there is a decline in the number of subject matter experts in any nuclear discipline.

6. Education for the 21st Century

A fundamental change has occurred in education during the ten years of the NTEC programme – the transition of the learning environment to fully include eLearning as a viable alternative to classroom based teaching, rather than just being used as added value. NTEC has fully incorporated this development and now has ten modules available over the internet as distance learning courses. These courses are studied over a whole semester, have the opportunity of a residential day during the face-to-face course delivery week and have exactly the same learning outcomes as the traditionally taught courses. Students, both full and part-time are able to access the courses from home and if they wish take a mixture of classroom based courses and distance learning course to balance their workload. The eLearning courses also allow students from all over the world to access the NTEC programme.

7. Conclusion

From a critical situation, following a decline of nuclear education in the UK, the Nuclear Technology Education Consortium has developed a successful nuclear science and technology Master's level programme that provides the quality of graduates required by the nuclear industry, with student numbers increasing year on year, and has maintained a sustained level of excellence and developed a sustainable funding model. Through adoption of modern teaching methodologies NTEC continues to be at the forefront of nuclear education, not only in content but also delivery. The next ten years will bring new challenges but the flexibility of the NTEC Master's level programme will enable it to adapt and prosper in the rapidly changing world of tertiary education.

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SUCCESS FACTORS OF INTERNATIONAL EDUCATION AND TRAINING NETWORKS

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ABSTRACT

In the last decade, several international education and training networks have been established in the nuclear field, striving to support – in general terms – the availability of qualified human resources in nuclear facilities (including research centers). Recently, several cooperation agreements have been signed between different networks with the aim to further boost the impact and effectiveness of their work. The networks have become active in different geographical regions of the world, and their creation has been supported by different international organizations. Consequently, for stakeholders in the nuclear field it is increasingly difficult to receive an overview, and to differentiate substantially between the education and training impacts on their own human resource issues.

In order to present an overview and a clearer view on existing education and training networks, and to assess the potential benefits of their work for concerned stakeholders, this paper presents 2 examples (European Nuclear Education Network / ENEN, European Fusion Education Network / FuseNet), comparing their history, their target groups and their members, their mission and objectives, their activities and working mechanisms, as well as their information and communication (websites).

The objective is to develop criteria and in particular success factors that may provide guidance for further development of international education and training networks.

1. Introduction

The Lisbon EU 2000 summit proposed the strategic goal for the European Union to become the most competitive knowledge-based economy with more and better employment and social cohesion by 2010. It said: "Although the number of nuclear scientist and technologist may appear to be sufficient today in some countries, there are indicators that future expertise is at risk. In most countries, there are now fewer comprehensive, high quality nuclear technology programs at universities than before. The ability of universities to attract top quality students, meet future staffing requirements of the nuclear industry, and conduct leading-edge research is becoming seriously compromised."

Consequently, different developments in the last decade made it necessary to enhance the capabilities of existing education and training institutions in Europe. For example, activities were undertaken to further harmonize educational curricula in Europe (Bologna and Copenhagen process) aiming at facilitating international mobility of the labor work force and enabling lifelong learning paths in response to continuous development of businesses and industries.

Driven by different challenges in the nuclear fission area – expected shortages of human resources and their competences for new built, plant modernization or decommissioning projects – and in the fusion area – expected shortages of human resources and their competences for the path to fusion power -, the European Union undertook appropriate actions early enough to meet these challenges.

Funded by different projects in Framework EC Programs (FP) 5 and 7, the implementation of education and training networks was supported by the European Commission. Two examples are presented in this paper; they shall serve to present at an overview level their missions and objectives, their working mechanisms, and their contribution to meeting the challenges as mentioned above:

ENEN - the European Nuclear Education Network,
FuseNet - the European Fusion Education Network.

This systematic overview shall serve for appropriate conclusions and a better assessment of other education and training networks.

2. History of networks

ENEN:
The "European Nuclear Engineering Network" (ENEN) project was launched under FP5 in January 2002, with the involvement of 18 European universities and 4 research institutions from 18 countries. Its main objectives were

- to deliver a European MSc degree in nuclear engineering and promote PhD studies,
- to promote the exchange of students and teachers participating in the network,
- to establish a framework for mutual recognition,
- to foster and strengthen the relationship with research laboratories, industry and regulatory bodies.

The European Nuclear Education Network (ENEN) Association was established afterwards by the partners of the project. It was given a more permanent character and a legal status by the foundation of the ENEN Association, a nonprofit international organization, on 22 September 2003 under the French law of 1901. Currently its executive office is hosted by the Institut National des Sciences et Techniques Nucleaires at the Commissariat à l'énergie atomique et aux énergies alternatives (CEA), Saclay site in Paris.

FuseNet:
The "European Fusion Education Network" (FuseNet) Project started in October 2008 as a Coordination and Support Action under FP7. The project consisted of eleven work packages, with a total budget of €2 Million. The project ran until October 2013 and has brought together a representation from the European fusion community with 36 participants from 18 countries, of which 22 Universities and 14 EURATOM research associations.

The project consisted of four groups of coordination actions:

- the establishment and running of the FuseNet network;
- development of individual learning opportunities and common educational goals;
- development of educational materials and hands-on experiments;
- and funding of joint educational activities

In continuation of the project, the FuseNet Association was founded in December 2010 under Dutch law as an independent legal entity. Currently its executive office is hosted by the Eindhoven University of Technology, Fusion / Applied Physics Department.

In summary, both networks were founded on the basis of research and development projects funded by the EU. The clear benefit of this approach was that during the course of the projects this enabled the founding members to develop a common understanding on the mission and objectives of the networks to be created. In parallel tangible results were developed that could then be further used by the new networks. Furthermore, the projects helped substantially in building international networks of different institutions that had a common high interest in education and training issues in their respective subject matter area, while relying greatly on the personal relationships built up during project execution.

3. Target groups and members

ENEN:

Currently there are 67 members of the ENEN association. The members are public or private corporate bodies that have a legal status, namely universities, research organizations, nuclear industry, and/or any other organizations involved in the application of nuclear science and ionizing radiation.

The members provide academic or professional education and training in the application of nuclear science and ionizing radiation, and/or commit themselves to supporting the ENEN Association, have a firmly established tradition of relations with some of the members in the fields of education, research and training, and are based in the European Union or in one of its associated or candidate member countries.

One has to distinguish between normal members / member institutions from outside Europe without voting rights / international institutions without voting rights. The last two member types must have a Memorandum of Understanding in place with ENEN, e.g. the Tokyo Institute of Technology, the International Atomic Energy Agency, or FuseNet. All members could also be grouped into the categories “education and training providers” and “end users”.

Members are located mainly in EU member states where nuclear energy contributes to a large extent to the provision of electrical energy; however, including also institutions from Japan, Russia, South Africa, Ukraine that are connected to ENEN via memorandums of understanding.

FuseNet:

Currently there are 59 members of the FuseNet association. They include university members, research institute members, industrial or other organization members (like the ITER Organization), but may also be grouped into the categories “education and training providers” and “end users”.

In regards to education, FuseNet activities shall address all education levels, from Master and PhD students to Post-docs. By the connection to industry, FuseNet wants to close the bridge between the educational system and the engineering needs in industry, aiming at developing a new generation of high quality students that are ready for large projects such as ITER, Wendelstein 7-X, or DEMO[1].

[1] See, e.g. https://www.euro-fusion.org/programme/

As fusion related research and development is undertaken in nearly all EU member states, either by research centers or directly by universities, members are distributed nearly homogeneously over the EU.

4. Objectives of networks

ENEN:

The mission of ENEN is the preservation and the further development of expertise in the nuclear fields by higher Education and Training.

Consequently, ENEN activities shall achieve the following objectives:

With respect to the education and training providers:

- to develop a more harmonized approach for education in the nuclear sciences and nuclear engineering in Europe,
- to integrate European education and training in nuclear safety and radiation protection,
- to achieve better co-operation and sharing of academic resources and capabilities at the national and international level.

With respect to the end users, such as nuclear industries, research centers, regulatory bodies and nuclear applications:

- to create and maintain a sustainable basis of nuclear competences in the EU,
- to maintain an adequate supply of qualified human resources for design, construction, operation, maintenance, and decommissioning of nuclear infrastructures, industries and power plants,
- to maintain the necessary competence and expertise for the continued safe use of nuclear energy and applications of ionizing radiation and nuclear techniques in agriculture, industry and medicine.

FuseNet:

The mission of FuseNet is to stimulate, coordinate and enable the best possible fusion education in Europe with the aim to enhance the expertise in the fusion area by higher Education and Training.

Consequently, FuseNet activities shall achieve the following objectives:

With respect to the education and training providers:

- to coordinate and facilitate fusion education in Europe,
- to share best practices
- to jointly develop educational tools,
- to jointly organize educational events,
- to provide matchmaking services with the end users.

With respect to the end users, such as industries, research centers, regulatory bodies and further fusion related organizations:

- to initiate research collaboration for PhD students,
- to support individual learning opportunities,
- to mediate internships for students,
- to identify fusion related competence needs and to initiate appropriate remedial measures.

In addition, the students have a central role in the FuseNet view and the student support schemes are the most visible and successful activities of FuseNet, with the aim to attract the best students and stimulate them to have access to excellent education.

With its current wide membership and support, and based on the specific competences on education and training embodied by its members, FuseNet can be considered as the European umbrella organization on fusion related education and training.

5. Activities of networks and working mechanisms

Both associations have as general structure a *General Assembly* (GA) that meets annually (in February / March), elects the members of the *Board of Governors* (BoG), and is the highest institution for deciding generally on the association, and in particular on its recurrent and specific annual activities. The BoG manages the association in the period between the GAs, it is led by a President (ENEN) respectively by the Chair (FuseNet), supported by the Executive Office (located at the site of the association) and a Secretary General.

The central hubs of information and communication (with private areas reserved for the normal and for the BoG members) are implemented via the respective web sites:

ENEN: http://www.enen-assoc.org/

FuseNet: http://www.fusenet.eu/

Apart from the basic operations that are mainly funded by the membership fees and that are needed to keep the associations alive, the activities of the associations, through which they aim to implement their mission and achieve their objectives, may be classified as follows:

a) Delivering certificates for Masters or even PhD theses based on specific criteria, with the purpose to stimulate international education or training activities while introducing a uniform high quality standard that make 'nuclear engineering' or 'fusion' a quality brand apart from a specialization,
b) Live meetings of members (GA preceded by a special event that is dedicated to a specific education and training topic) as well as of Masters or PhD students, e.g. in connection with a conference and handing over the certificates,
c) Specific projects that will contribute to achieving the objectives of the associations, and that are funded by external sources, providing a unique opportunity for the members to cooperate while also following their own specific interests in education and training.

ENEN:

The General Assembly 2015 decided on an Action Plan for 2015-2016, for its implementation six Working Areas have been defined for the period 2015-2016:

1. ENEN Management Area
2. Quality Assurance Area
3. Teaching and Academic Affairs Area
4. Advanced Courses and Research Area
5. Training and Industrial Projects Area
6. Knowledge Management Area

As for activity class a):

ENEN awards the *European Master of Science in Nuclear Engineering* (EMSNE)[2], i.e. a certificate, if a set of requirements have been fulfilled, namely at least 5 years university education, at least 60 ECTS must be "purely nuclear", 20 ECTS must be obtained from a "foreign" (different country) institution that is a member of ENEN, Masters thesis.

Furthermore, an *ENEN PhD Prize*[3] is awarded to young scientists that start their career finishing their PhD. The prize is based on the judgment of a jury that evaluates submitted papers and the live presentations of the respective PhD theses during the *ENEN PhD Event*.

[2] See http://www.enen-assoc.org/en/emsne/information.html

[3] See http://www.enen-assoc.org/en/phd/announcement.html

As for activity class b):

In 2016, the GA was hosted by the European Commission JRC-IRMM in Geel, Belgium, providing the opportunity for a technical visit of the IRMM, in addition to the Special Event (presentations by invited speakers) on “E-learning and MOOCs for nuclear education and training, preparing for ANNETTE”.

As for the EMSNE laureates, each year they receive the Certification diplomas in a relevant ceremony. In previous years this ceremony has been held, with the support of the IAEA Nuclear Knowledge Management section, as a side event of the IAEA General Conference, in Vienna, Austria.

The *ENEN PhD Event* is a 1-2 days session where 10-12 PhD Finalists, nominated by ENEN Members and selected by the ENEN PhD Prize Jury, present their research in a competitive but friendly environment.

As for activity class c):

Currently ENEN is involved in 4 education and training projects (ANNETTE, NUSHARE, PETRUS III, EUJEP 2)[4], all funded by the European Commission as Coordination and Support Actions, ENEN being the Project Coordinator while (some) ENEN members participate as partners in a project specific consortium.

FuseNet:

The General Assembly 2015 decided on Work Packages to be implemented in the period 2016 – 2017, see below. They are divided into a set of core activities (Basic Operations) and all other activities (Extended Operations), and each one is managed by its own Work Package leader. The Basic Operations are largely covered by the membership fees. The Extended Operations are intended to further achieve the objectives of the association and initiate, coordinate and execute activities for the benefit of fusion education and training in Europe. FuseNet looks for external sources to fund these activities, currently this is done by EUROfusion and the European Commission.

Basic Operations (Recurrent)

WP1 Management and Support

WP2 Funding Opportunities

WP3 Website and Outreach

WP4 Academic Council

Extended Operations - EUROfusion contract B

WP5 Organization of annual Fusion PhD event

WP6 Support to PhD students

WP7 Support to the development of new educational activities

WP8 Development of Joint Educational Tools

WP9 Industry and Training

WP10 Consultancy for PhD programs

WP11 Support to Master students

Extended Operations - ANNETTE (EC) Project

ANN ANNETTE Project

As for activity class a):

FuseNet has established academic criteria for the award of European Fusion Doctorate and Master Certificates. The purpose of these criteria is to stimulate a high level of fusion educa-

[4] For more information on these projects, see http://www.enen-assoc.org/en/training.html

tion throughout Europe, introducing a uniform high quality standard that make 'fusion' a quality brand apart from a specialization.
Here, the Academic Council of FuseNet advises on all academic matters, including the joint criteria for the European Fusion Master and Doctorate and the accreditation of educational institutions or individual theses according to the joint criteria.
Furthermore, within Europe there are several doctoral training networks in the field of fusion. Whereas these networks are quite distinct in character, geographical spread and funding structure, there are also strong links between them through FuseNet, as representatives of these networks are members of the FuseNet BoG. All training networks comply with the joint criteria for the award of the European Fusion doctorate certificate, namely the

- Fusion Doctoral Training Network (UK),
- Erasmus Mundus Fusion Doctoral College (Universities from Gent, Madrid, Stuttgart, Lorraine),
- European Doctoral Network (Padova-Lisbon-Munich).

As for activity class b):

In 2016, the GA was hosted by the ITER Organization in Cadarache, France, providing the opportunity for a visit of the ITER construction site.
The European Fusion Master and Doctorate certificates are handed out to nominated European students that obtained a Master or PhD diploma in Fusion Science and Technology and that have fulfilled the related criteria. The ceremony is held at a fusion related site in combination with a specific event, e.g. in 2015 after the GA in JET, Culham, UK.
Additionally, FuseNet coordinates and supports the organization of the annual FuseNet PhD event. The events provide an opportunity for European PhD students to discuss their work with each other and with researchers from the international fusion community, and it gives them the opportunity to make useful contacts for their professional career. The 2015 edition of the event was organized by Czech Technical University in Prague, Czech Republic. With an attendance of 130 PhD students, the fifth FuseNet PhD event in fusion science and engineering was the largest up to date.

As for activity class c):

Currently several activities of FuseNet are funded via a contract awarded by EUROfusion, see list of Work Packages above. These mainly deal with activities that are closely connected to fusion master and PhD students, e.g. the certificates and events already mentioned, but also the financial support to students to give them access to excellent training and educational activities.
Here, another important Work Package deals with industry, with the objective to involve fusion related industry in the training of engineers and students, and to establish links and collaboration with industry to identify short / middle / long term education and training needs.
Finally, FuseNet also executes a Work Package of the ANNETTE[5] project, namely the nuclearization of fusion – an important issue with high impact on design and construction of fusion power facilities.

[5] See for example http://www.fusenet.eu/node/1073

6. Network information and communication (websites)

ENEN:

The website provides important information about ENEN – its mission and objectives, its activities (in particular the projects it is involved in), its members and its international partnerships. Furthermore it provides information about future important education and training events, e.g. conferences or summer schools. And finally the ENEN database allows users to search for education and training courses that are offered by ENEN members.
As a matter of course, it also provides a private space where information for normal or BoG members is made available.

In parallel to the ENEN web site, ENEN runs a dedicated channel on YouTube, as well as Facebook, Google+ and Twitter accounts.

FuseNet:

As in the case of ENEN, the website provides important information about FuseNet – its mission and objectives, its activities (in particular the projects it is involved in), its members and its international partnerships. Furthermore it provides information about future important education and training events, e.g. conferences or summer schools, but also a lot of information about bachelor and masters study opportunities, PhD and PostDoc positions, etc. You can also find teaching materials here, and you can learn about the possibilities to get financial support.
The website also serves as the matchmaking platform where students can find industrial internships, as well as places where fusion PhD and PostDoc positions are advertised. All information on other activities of FuseNet may be found on the web site, too. Finally, the web site presents articles on recent developments in fusion, 'eye-witness reports' of participants in FuseNet activities, 'photo-of-the-month' etc.
Like with ENEN, it also provides a private space where information for normal or BoG members is made available.

Also FuseNet can be connected to via Facebook, and can be followed via Twitter. In addition, the FuseNet web site allows users to register and to open a blog, or to post comments.

7. Conclusions

Assessing education and training networks that are aiming at developing and maintaining competences of human resources in a specific technical domain – as presented in this paper - the following factors appear to be crucial for their success:

1. Public education and training related activities that provide appropriate diploma or certificates in line with the network's mission,
2. An effective, up-to-date hub of information and possibly also communication between the members and outsiders,
3. Projects in which members of the network are involved in, and that develop tangible results to achieve the network's objectives.

Ensuring the success of an education and training network certainly requires the engagement of their members. Although the effectiveness of an executive office will contribute to a great deal, this effort – the basic operation - can only be funded partially by the membership fees. Consequently, the network must be involved in externally funded projects that are in-line with its objectives. Currently, only this mechanism supports the long-term operation of the network.

As regards ENEN and FuseNet, the presentation in this paper shows that their long-term operation definitely will contribute successfully to the long-term sustainability of human competences in the area of nuclear and fusion, assuming long-term availability of projects or more sustainable funding.

Finally, the scheme used in this paper can be applied to assess other education and training networks, possibly also to identify areas of further improvement.

In closing this paper it is worth mentioning that ENEN and FuseNet signed a Memorandum of Understanding in Culham, UK, in February 2015. This represented an important step for the cooperation of the two networks, which are aiming at leading education and training in the two respective nuclear fields in Europe in the years to come.

GLOBAL NETWORKING FOR NUCLEAR LEADERSHIP

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ABSTRACT

The nuclear field is a complex and diverse area, including a multitude of different participants, directly and indirectly engaged in nuclear, facing issues such as the ageing workforce, rises and falls in supply and demand of trained staff. In this context, extensive networks are crucial for managing projects that cross borders with regards to strategic management and knowledge sharing.

To navigate the maze of networks, it is important to understand that there are different types of networks that fulfil different needs. They play a key part in understanding and facing new challenges inside and outside one's organisation. Early on in an individual's career, the network will have an operational focus looking at fulfilling team objectives and goals within the organisation. However as individuals and organisations transition towards leadership they are required to develop a broader and more strategic outlook, focusing on a wider context of variables and a global vision for the future. Higher stakes will ride on leaders' decisions and their networks will therefore need to evolve to provide them with the insights and connections to succeed at new challenges.

The World Nuclear University (WNU) Summer Institute is a case study for networking during this transition to leadership roles. This nuclear training programme is designed to serve as a platform for forming both horizontal and vertical networks within the nuclear area. Each year brings together groups of individuals in this transitional phase with a similar focus on nuclear energy, from government, industry, regulatory bodies, education, and research amongst many others from more than 30 countries. This opportunity allows them to firstly expand their personal networks based on friendships, and later through the alumni network, form a strategic network for professional activities.

This paper looks existing writing on networks and the impact on the transition to leadership roles. Data collected in WNU alumni and company surveys is analysed, and finally this paper explores various WNU tools for alumni engagement.

1. Introduction

Networks are ever more the focus of leadership development programmes, especially in the context of moving towards social or systemic changes. This is not only regarding individual leadership within separate organisations, but leadership for industries as a whole. The nuclear industry is subject to various arrangements for cooperation among utilities, and internationally, among governments and agencies such as the International Atomic Energy Agency (IAEA) and the OECD-Nuclear Energy Agency. Networks are important, not only to support leaders but also to tackle challenges faced by the nuclear industry, such as public engagement, with the industry as a whole learning through cumulative experience and sharing knowledge. At the same time, it is important to develop leaders who are able to understand issues surrounding nuclear with a global perspective.

The creation of the World Nuclear University (WNU) bears testament to international cooperation in the nuclear sector. In 2003, the IAEA, the World Nuclear Association, the World Association of Nuclear Operators (WANO) and the Nuclear Energy Agency (NEA), along with academic and research institutions from 23 countries, established the WNU to promote international cooperation on the peaceful applications of nuclear science and technology in support of global sustainable development, as well as to train future nuclear leaders. This cooperation has further developed over time, to now include more international and regional associations and educational institutions. To date, over 4000 participants from almost 80 countries having attended one of the WNU programmes.

The WNU Summer Institute was launched in 2005, for professionals from industry, research centres and regulatory bodies, selected by their companies for their academic or professional excellence, and their leadership potential, to train together for six weeks in the summer. Sponsorship for international organisations further helped to ensure the diversity of the group, allowing access to high potential candidates from developing nuclear countries to also participate in the course and share their perspectives. Since the inception of the WNU the IAEA has been the leading sponsor for the WNU Summer Institute, awarding several full scholarships to candidates from around the world, followed by the Japan Atomic Industrial Forum (JAIF) and the World Nuclear Association. WANO also joined this support with three scholarships and the Korea Nuclear International Cooperation Foundation (KONICOF) with one in 2016.
In the analysis of global networking for nuclear leadership, this paper looks at the WNU Summer Institute as an existing case study on effective networking, followed by an overview of some existing writing on networks. Finally it draws some conclusions and lessons learned for future initiatives.

2. Summer Institute: a case study

The Summer Institute is the World Nuclear University's flagship programme aimed at developing leaders in the nuclear area. This programme has been successfully operating for the last 12 years creating a global network of 917 individuals from 78 countries. This programme was created with a view of developing a stronger, more global and knowledgeable leadership for nuclear energy. The WNU Summer Institute has a three-fold training philosophy focusing on nuclear knowledge, leadership skills development, and networking.

2.1 Nuclear training

The course provides a distinctive experience by covering the full value chain and different roles within the nuclear area, taught by experts and global nuclear leaders. The content of lectures is up-to-date and based on international recommendations and the real world experience of the presenter, covering one of the many topics related to nuclear energy. The overall experience provides participants, referred to in the WNU as 'fellows', with an insight into the latest nuclear industry developments and an international perspective through first-hand experience. At the end of the programme, fellows participate in a "network for nuclear innovation", where they research and discuss specific topics from new angles in order to develop new solutions.

With a view to providing a comprehensive approach, the curriculum focuses on four key topics:

- The global nuclear setting for a broad understanding of the world energy context.
- Nuclear industry and applications providing up-to-date knowledge on the nuclear fuel cycle, energy supply, innovation, new build and applications of ionizing radiation.
- International regimes including nuclear law, safety, security and safeguards.
- Leadership, project management, knowledge management and communications.

The Summer Institute consists of 270 hours of activities with an average of 8.5 hours/day but less than 20% of this time is spent in traditional classroom lectures. The rest of the time is devoted to workshops, case studies, invited leader presentations, simulation and other group work. One further important training activity is the technical tour, where fellows are given the opportunity to visit a range of nuclear installations relevant to fuel supply, energy production, and waste management, depending on the location of the Summer Institute in that year. In 2015, for example, fellows were able to visit the Äspö Hard Rock Laboratory for the Swedish long-term radioactive waste repository, 450 metres below ground, guided by experts who work in this field (Figure 1).

Figure 1 - WNU Summer Institute 2015 fellows at the Swedish Äspö Hard Rock Laboratory

2.2. Leadership skills

Typically, each the Summer Institute brings together 70 individuals from about 30 countries. Each participant will be selected to participate in the Summer Institute by their organisation and then will apply to the WNU, going through a selection committee that discusses each application, taking into account the expertise and knowledge of the candidates, their professional and academic achievements, and most importantly evidence of leadership or potential of leadership.

Alongside nuclear topics, the Summer Institute aims to build essential competencies to prepare future leaders for the nuclear area. Through working group sessions which take place every afternoon, composed of one mentor and up to 10 fellows, participants are called upon to discuss and debate different topics, using modern training methodologies. Fellows are given tasks, case studies, interactive platforms, competitions, and simulations to work on as a group. The aim here is encourage individuals to develop and voice their opinions on selected topics, and debate this in the context of their group which will likely have members from all different areas of research, industry, or government and from any number of countries. This cross-cultural exposure is essential to building an international understanding of these issues, and furthermore to gaining the confidence necessary to discuss with and learn from others. In the distribution of tasks or roles, each fellow is called upon to take the lead, to coordinate team members, to present outcomes and to collaborate with a diverse team.

Communication skills are a key focus at the Summer Institute, and each morning fellows from one country will be selected to give a brief interactive presentation of their culture, update the rest of class on recent developments in the nuclear sector, and practise announcing a typical operational nuclear safety message.

2.3 Maintaining and growing a global horizontal and vertical network

Once accepted in the Summer Institute, the fellows have the opportunity to openly discuss topics together and experiment with new ideas, building ties of trust and knowledge.. These horizontal ties created at the Summer Institute's working groups and cultural and social events are maintained after the Summer Institute has ended. In addition, there are opportunities for vertical networking encouraged by the WNU. Fellows are actively encouraged to ask questions and engage with the mentors, lecturers and invited leaders inside and outside of the lecture room. Moreover, the Summer Institute offers the infrastructure for the fellows to organise extra-curricular sessions where they can discuss topics in further detail with the faculty.

To keep this network alive, the WNU uses LinkedIn with alumni from all years as well as email updates to facilitate communication after the Summer Institute has ended, and also provides a web platform for continued engagement. Moreover the WNU website has a private area for fellows to refer back to the training content and continue discussions.

Alumni Assemblies, which bring together fellows from various years for a short workshop session, take place every two years. These have been held at the IAEA headquarters in Austria (2012), Oak Ridge, USA (2014) and Beijing, China (2016). Finally, participation in conferences, such as the World Nuclear Association Symposium or International Atomic Energy Agency meetings are also opportunities to connect with alumni, and ex-faculty.

Responses from the surveys show that the opportunity to train over six weeks, as well as to network intensively, has long-lasting benefits to individuals and their organisations. The participants return to their roles better equipped and more confident in facing new challenges, with a fuller understanding of the broader industry and better able to increase networking. By bringing individuals from all over the world to train together, the WNU is able to build ties of trust and understanding across countries and organisation that will only grow in the future, adding to the overall health of the sector. It is essential to maintain these connections and create new ties in order to promote confidence, international collaboration and knowledge sharing.

2.4 Continuous evaluation

With a view to maintaining the quality of the programme, the WNU continuously evaluates its course content. This is done with the support of a programme committee as well as by requesting feedback and assessment reports from Summer Institute fellows and alumni. The WNU bases its review of Summer Institute course content on Kirkpatrick's [1] four levels of training.
The first level, *Reaction,* takes the form of ongoing surveys on the degree of satisfaction of the participants with the programme, as well as the overall infrastructure and organisation. These surveys receive very positive responses and suggest how elements of the programme, such as the mobile application for smartphones and tablets or the private website, could be improved to enhance their experience.

The second level, *Learning,* is about the principles, facts and techniques that were learned. It is the 'global impact evaluation' carried out at the end of the 6 weeks, where participants are asked how effective the Summer Institute has been and if they feel they have increased their knowledge base, their skills, and their confidence. The fellows perform a self-assessment to verify their learning. The following quotes illustrate some of the general feedback on their experience:

> *"This was a one of a kind experience. It was hard leaving my family for six weeks but completely worth it. I grew so much by listening to the lectures, visiting other sites and by the day to day interactions with people from all over the world."*

> *"Warm friendship, respect, sharing knowledge, thoughts and skills – WNU SI is all of this. Each and every one of the fellows and mentors influenced me and my development. I hope that I contributed to their experience of WNU SI as well.*

The third level, *Behaviour,* is about the changes in job behaviour resulting from the training programme. The WNU assessed this level by means of a long-term evaluation questionnaire, which was sent out to SI alumni, asking how the SI had affected their careers in the following years [2]. Of the 156 respondents, 89% identified a positive consequence due to their participation in the SI. About three-quarters (74%) reported that they were better able to communicate effectively with high-level managers since attending the SI, and (Figure 2). 84% were more open to new professional relationships.

Fig. 2 – Selected responses to the question in the long-term evaluation survey: "After the SI, have you noticed an increase in your capacity to communicate with (choose as many as you want)?"

Nearly all participants (96%) reported improved understanding of nuclear topics that could be incorporated into their working lives and 95% maintained their enthusiasm for continuous learning. The following quotes illustrate this:

> *"I met and gained access to people I never would have had access to otherwise."*

> *"Before my attendance I had very little understanding of how politics, economics, the environment and public speaking related to my work. This all changed at the Summer Institute."*

The final level, *Results,* evaluates the impact of the training on the participants' organisations. In 2016, the WNU Coordinating Centre received feedback from 10 companies which regularly send fellows to the Summer Institute. The respondents were from the human resources sector of industry, regulatory bodies, research institutions and professional associations, from Argentina, Belgium, Canada, France, Ghana, Japan, Nigeria, South Korea, and the United Kingdom.

Sixty percent of the respondents said that participation at the Summer Institute was based on an annual selection process, with "recognised leadership potential" selected by 80% and "role requiring an international network" selected by 40% in the criteria for putting forward their candidates. When asked to rank the reasons for sending participants to the Summer

Institute, “extensive and international networking” was ranked in the top three, after “global perspective on current nuclear topics” and “leadership development”. Table 1 shows that fellow are more motivated after the Summer Institute.

The participants of the WNU SI are:	**Agree or strongly agree**
More motivated by their experience and looking forward to new challenges	100%
Able to anticipate how changes in the external environment will affect their work	89%
Approach to leadership roles with confidence.	78%
Eager to teach the others	67%
Able to perform tasks in a shorter time and more effectively	67%

Tab.1 -Results of Summer Institute survey of companies

The respondents mentioned that the participants in the Summer Institute improved their communication skills and the attitude towards the job, and demonstrated more innovative and strategic thinking.

The following quotes from alumni illustrate some of the benefits to their companies resulting from their participation in the Summer Institute [2]:

> *“Although we are involved in uranium mining, the public often has broader nuclear questions that I am better able to answer now.”*

> *“It has truly motivated me to stay within the nuclear industry.”*

3. The importance of networking

Leadership roles go beyond working on operational challenges. To lead, individuals must take a broader and more strategic approach to their organisation and their industry to be able to build successful teams and work towards long term goals. The network is important to allow for a flow of resources, information and skills that will make this possible. Productive and high performing individuals move up through the ranks because of the quality of their work when completing current operational objectives within the organisation. When moving to a leadership role, individuals will be confronted with a new set of responsibilities including inspiring their team, working towards long term goals and making strategic decisions. Networking will be essential to expanding and developing the skills and knowledge necessary to tackle these new responsibilities. Despite its important role, networking can often turn out to be a significant hurdle for some individuals, due to the time and effort it requires and furthermore the range of social skills it will call upon. Potential leaders can often limit themselves by avoiding networking as something negative, for example ’politics’. This is why it is important to understand what networks and how they impact on leadership, but furthermore how individuals can create quality networks in way that is authentic to them.

3.1 Networking and leadership development

Companies recognise the importance of leadership and networking skills, as well as the discomfort that some people feel in extending their network when starting a new role. It is very easy to remain within the safety of the immediate network, but this does not make for good leadership. Initiatives launched by companies, such as coaching, mentoring, and social events, to facilitate networking can help overcome this challenge and help support employees as their careers evolve. Such initiatives can be vertical or horizontal within the organisation, and should help them learn more about the company, develop their social skills and discuss ongoing projects or challenges from various perspectives.
Networking within a small team is part of the daily routine. However, when moving onto a leadership role, individuals must connect with people from all over the organisation, and be

able to understand the direction that is being taken. Good leaders must be able to act strategically, keeping in mind future performance as well as present day activities.

3.2 Operational, personal and strategic networks

Ibarra and Hunter [3] describe three different types of networks relevant to the manager: operational, personal and strategic. Operational networks are the networks used to fulfil local operational needs or meeting objectives within the organisation. Personal networks on the other hand, are usually outside the organisation and based on affinities or interests, such as a sport, a book club, or any other formal or informal social group. This is where managers can turn to in order to receive advice or learn from individuals, who are external to their team and their organisation. This is also where they can enhance their social skills and ultimately their networking skills. Expanding personal networks enables individuals to feel comfortable with connecting with others based on common interests, shared goals, trust and reciprocity. Personal networks are important for the development of leaders, and although external to their working environment, will indirectly impact on their leadership.

During the six weeks of the Summer Institute, while away from their family and friends, fellows connect with others in the programme who have similar interests to them outside of the professional context – for example, sports, culture, or music – and they will organise their own social activities based on these common interests. Moreover, fellows come from different fields and countries in different stages of development. From nuclear engineering, to law and regulation, to communications and international relations, each fellow has a very different professional and cultural background. The social context creates a suitable environment to connect with others based on common interests, and to learn from different experiences and perspectives. Cross-industry experience is also beneficial as it this contributes to motivation, problem solving, and innovation.

The foundation for the strategic network is often laid down in the personal network. Horizontal and vertical relationships in the professional sphere are necessary for leaders to understand the overall picture surrounding their role, to have access to all the relevant information and support to be able to achieve organisational goals.

It should also be noted that operational, personal and strategic networks are not mutually exclusive and, despite the different functions, can evolve over time.

At the Summer Institute fellows are given the opportunity to meet with peers and leaders from many countries. Connections which initially fall into the category of the personal network may evolve over time to the strategic network, as careers progress and as their roles become more relevant to each other. Discussing relevant topics with mentors and lecturers is also a good way for them to develop their understanding of nuclear and business, improve communications skills (Figure 2), and build connections that last beyond the Summer Institute. The personal network built at the SI helps them connect with a large number of nuclear companies or high-level people in business and government around the world.

3.3 Quality over quantity

Willburn and Cullen [4] describe the importance of the structure of a good network, which should have three qualities: *open*, which includes individuals who are not all connected with each other; *diverse*, as the network reaches both vertically and horizontally towards different stakeholders, demographics and geographic boundaries; *deep*, as they are important relationships that allow for exchange of information, resources and skills, as well as social support and camaraderie. These ties provide mentorship, advice but also professional collaboration which can determine the success and the advancement of leaders.
Social networks provide more opportunities for participants to build long-lasting and meaningful relationships. This is often the case during longer academic courses such as

graduate and undergraduate studies. In more practical terms, for professional training funded by companies who are not able to do without staff for extended periods of time, the Summer Institute's six-week programme is a good compromise, whereby fellows are able to forge strong ties through shared experiences and interests with individuals from all over the world, complementing their pre-existing network with new connections. Willburn and Cullen also highlight the importance of 'frequency', which refers to keeping networks active, with a flow of advice, information and resources. Using the network strengthens it, whereas leaving it dormant until it is needed might result in connections not being prepared to deliver the required support.

4. Conclusion

This paper draws some lessons that can be applied to future initiatives. The first challenge is how potential leaders can develop so that they can fulfil their full potential. Some exceptional individuals may be able to create their own strong international networks by themselves, but even these individuals will likely have benefitted from some form of mentorship or sponsorship, whether formal or informal. Human resources and talent development are able to help with initiatives to accompany individuals on their development. Mentoring and coaching initiatives are essential to developing a strategic view; however it is equally important to make connections both horizontally and vertically within and outside of the organisation.

Both personal and strategic networks are necessary. When transitioning to a new role it is an important time to extend the personal network, for skills development, coaching, advice and knowledge transfer. The strategic network has a direct impact on leadership, and provides the information and perspective for achieving organisational goals effectively. A good network is not necessarily a vast circle of connections, but a deep, open and diverse one. It is equally important to keep a network alive and active with a flow of information, advice and resources so that it will continue to help leaders as the organisational needs develop and change. Lastly it is important to note that with each new leadership role, the leaders' network will also have to transition and evolve to match the new requirements of their role.

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EXAMPLE ON HOW NUCLEAR ENGINEERING & SCIENCE INTERNATIONAL NETWORKS COLLABORATE SUCCESSFULLY WHEN BUILDING ON THEIR MUTUAL STRENGTHS

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ABSTRACT

Sustainable operation of nuclear installations and power plants worldwide depend heavily on how procedures and standards are implemented as much as on how the human-machine interface is responsive to sudden mechanical failures, natural disasters or human mistakes. These environments are best managed within well-established practices defined and known as **safety culture**. A safety culture concerns the comprehensive attitudes and characteristics of both individuals and organizations. According to the U.S. Nuclear Regulatory Commission, nuclear safety culture is defined as the core values and behaviours resulting from a collective commitment by leaders and individuals to emphasize safety over competing goals in ensuring protection of people and the environment. The root of securing the safety culture and providing its sustainability in the existing and future nuclear power plants and facilities lies in very early educational practices. An effective positive safety-culture is essential to nuclear safety and can help prevent errors and misconduct by ensuring expectations and consequences are clearly stated and understood. Additionally, the networking in between the institutions nationally and worldwide is crucial in learning, assuring and practicing an ever improved the culture of safety and its fundamental principles. In the last two years, the University of Utah and Okayama University Center for Safe and Disaster Resistant Society have developed a **bridge** of safety culture learning and training, in engaging their own domestic networks. We thus introduce in this paper how such a uniquely created nuclear engineering & science international networks resulted in a successful building of a safety training and education utilizing their unique and mutual strengths.

1. Introduction

Nuclear power is utilized in many countries, and the safe use of nuclear energy is our common interest. After the Fukushima accident, people in Japan in general feel anxious about nuclear engineering and technology. There is an urgent need to rebuild the public trust that has been lost in safety of nuclear power. Science and technology should be linked to the welfare for human beings. Our societies need to be assured regarding the safety and reliability of industrial facilities to prevent accidents. Consequently, a number of activities, countermeasures, and assessment techniques have been proposed. The important role of academia is to challenge the keen social issue and to supply well-educated professionals and technicians continuously. There is a need to train and teach the field of nuclear safety in thus generating a pipeline of experts and establishing a culture of safety. The current nuclear workforce worldwide is nearing retirement and as they retire, they will take with them a large amount of experience and knowledge. New methods to meet the needs and styles of learning for the younger generation need to be developed and employed to fill the nuclear workforce void.

Safety culture concerns the comprehensive attitudes and characteristics of both individuals and organizations. Each person and groups of people have different values and beliefs, which ultimately affects social awareness and creates difficulties in partnership. Therefore, to build and enhance safety culture in our society and workplaces, engineering safety education is especially important. The University of Utah Nuclear Engineering Program (UNEP) and Okayama University Center for Safe and Disaster-Resistant Society aim is to cultivate the engineering safety culture in each engineer and stakeholder. By engineering safety education and research activities, we are to achieve the following:

1. Safety responsibilities concerning individuals and organizations;
2. Share information for having a mutual understanding and willingness about risk and safety; and
3. Promoting the inheritance of technology and nuclear engineering safety knowledge.

2. Nuclear Engineering & Science International Networks: Example of a Successful Collaboration

2.1 The University of Utah Nuclear Engineering Program (UNEP)

The University of Utah Nuclear Engineering Program (UNEP) in Salt Lake City, Utah, U.S.A has established and continues to build a strong nuclear engineering safety culture by developing class and laboratory soft skills training and activities and by developing new collaborative network activities [1], [2]. The UNEP houses world-class laboratories and facilities, including the University of Utah TRIGA Reactor (UUTR) (Figures 1 & 2), Radiochemistry (Figure 3), Microscopy (Figure 4), Advanced Radiation Simulation, Radiation Measurement, and Neutron Activation Analysis (Figure 5) Laboratories. In addition, in 2014 UNEP acquired an additional laboratory space of newly renovated clean laboratories for trace actinide analysis and spectroscopy (Figure 6). The UNEP faculty are committed to building technical expertise and leadership skills in students while encouraging them to strive for innovation; to develop life-long learning skills by way of experimental training and hands-on schooling.

Figure 1: UUTR Control Room

Figure 2: UUTR and UNEP Students

Figure 3: Radiochemistry Lab

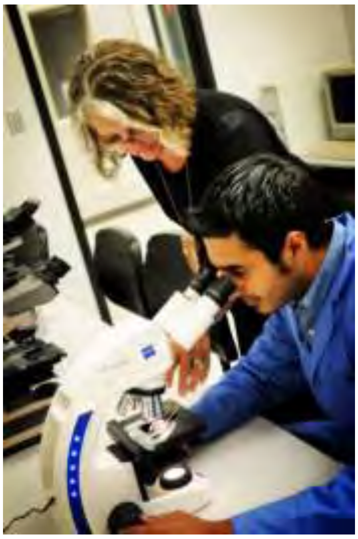

Figure 4: Microscopy Lab

Figure 5: Neutron Activation Analysis Lab

Figure 6: Trace Actinide Analysis Lab

2.1.1 The UNEP Transformation

In the Fall of 2009, UNEP underwent a dramatic transformation to expand its curriculum and develop new research endeavours attractive to current student generations while simultaneously addressing the needs and expectations of the nation's nuclear industry. The changes in the program from 2009 are:

- In 2009, a **Nuclear Engineering Minor** was developed and approved by the Board of Regents in May of 2010. The Minor started in the Fall of 2010 with the goal to increase the number of students in UNEP, recruit and retain an increased number of graduate students, and provide a unique education for engineers in demand by the State, Nation and the World [3]. As of 2015, over 300 students have taken classes with 27 enrolled in the minor program as of Fall 2015.
- In 2010, a **Senior Reactor Operator Training Program** was established and continues to be managed by the staff with the goal to prepare students in obtaining licenses to operate the UUTR.
- In 2010, the **Graduate Program Curriculum** was advanced to meet the challenges of the 21st century nuclear industry and national needs including, radiochemistry, nuclear medicine, nuclear forensics, advanced reactor design, and advancements in nuclear fuel reprocessing. From a handful of graduate students in the fall of 2009, the UNEP graduate student body increased to around 30 students per year, peaking with 44 in Fall of 2015.
- The **Outreach Program** was revitalized in reaching students from elementary to high schools, other universities, government organizations, industry and first responders in the region and nation-wide. In the last four years, the reactor hosted 3,300 visitors.
- In 2012, a **Nuclear Safety Culture** paradigm was established, using an industry proven corrective action program (CAP) intelligent computer software, DevonWay, to train future nuclear scientists and engineers on the importance of nuclear safety and operate the UUTR facility under the same approach [4].
- In 2015, a **reactor console clean-up** and relocation was conducted along with replacement of the fission counter and two uncompensated ion-chambers.

UNEP's new graduate program provides the students with a wide range of opportunities in developing skills expected by industry, national labs, and the private sector in nuclear engineering and associated disciplines, by exposing them to challenging projects (as part of regular course work and/or thesis research) with the focus on problem-solving engineering concepts. The majority of all nuclear engineering courses and laboratories taught at UNEP employ the use of the UUTR to demonstrate the *core* nuclear engineering concepts.

2.1.2 The UNEP Safety Culture

Since 2012, UNEP has implemented a nuclear engineering safety culture by training and

focusing on the following nine safety culture factors:
1. Management Commitment to Safety
2. Willingness to Raise Safety Concerns
3. Decision Making
4. Supervisor Responsibility for Safety
5. Questioning Attitude
6. Safety Communication
7. Personal Responsibility for Safety
8. Prioritizing Safety
9. Training Quality.

The United States research reactors are not required to evaluate and measure nuclear safety culture. The UUTR facility is the only academic research facility that is operating under the nuclear safety culture principles that were introduced by Jevremovic in 2012. The UUTR facility uses a corrective action program (CAP) tracking software, DevonWay, where the safety culture factors at the UUTR are recorded [3]. The 9 factors of safety culture are also closely tied to the Institute of Nuclear Power Operations (INPO) "Traits of a Healthy Nuclear Safety Culture" [5]. The UNEP has become a leader in developing and enhancing nuclear safety culture. The 1st Symposium on Engineering Safety Culture and Innovations was hosted recently in Salt Lake City, Utah, USA on March 15, 2015. The faculty and staff continue to work on and research areas of safety culture and how it can be better ingrained in the students that graduate.

2.2 Okayama University, Center for Safe and Disaster-Resistant Society (CSDRS)

Since 2008, Okayama University have run the project "Engineering Research and Education on Safety and Security under Low-level Radiation Environment". [6] In 2014, Okayama University established the Center for Safe and Disaster-Resistant Society (CSDRS). This new center launched as to take over academic activities that were from preceding project. The main mission of CSDRS is to cultivate the safety culture in each engineer and stakeholders through the education, training and applicable research curriculum provided by the experts. CSDRS has successfully developed a networked collaboration with domestic and international organizations by exchanging the students and researchers. Japan Nuclear Education Network (JNEN; associated with Okayama University, Tokyo Institute of Technology, Osaka University, Kanazawa University, Fukui University, Ibaraki University, Nagoya University and JAEA in Figure 7) includes seven Japanese universities via network.

Figure 7. The Center for Safe and Disaster Resistant Society and JNEN

The universities of JNEN have cooperated with related organizations to educate students as professionals with a higher sense of safety culture ethics. CSDRS conducts research and has built Master and Doctoral Course Programs. In Japan, most of the industrial complexes are located near seashores, and it is an urgent and important issue to prioritize research on safety and disaster-resistant societies. It is imperative to produce well-educated engineers who can achieve a safety environment for our society. CSDRS is open for all faculties of Okayama University, and students from 3 graduate schools, i.e. Graduate School of Health

Sciences, Graduate School of Environmental and Life Sciences and Graduate School of Natural Science and Technology. Key topics covered are radiation measurement for protection and human health, safety design for disaster-resistant nuclear facilities, safety culture, safety management and public communication. CSDRS also prepares professional education courses for those already working in the industry. CSDRS has financial support by Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

2.2.1 Educational Activities of Okayama University

Since 2008, Okayama University is continuing the special education course for graduate students regarding nuclear safety. Table 1shows CSDRS's size and enrolments between 2008 and 2015. CSDRS has started a new special program course in 2015 called "Toward a Safe and Disaster-Resistant Society." Students who have completed this course and met the completion requirements is conferred Certificate of the course. The graduates in this course have obtained jobs in the nuclear industry and other various industries. It has promoted the understanding of the nuclear technology to the Japanese. CSDRS can make effective connections of graduates so that they improve safe society concepts to help each other. The educational background of the students tended to vary from the pure sciences to engineering. Both governmental and private sector businesses could benefit from the graduates.

Table 1: Students newly enrolled per year

Year	The number of students (Master Course)	The number of students (Doctoral Course)
2008	7	Not started
2009	8	Not started
2010	13	2
2011	10	3
2012	11	3
2013	11	4
2014	7	1
2015	18	2
Total	85	15

2.2.2 Enhanced Stakeholder Knowledge

Safety culture [7] is essentially important in nuclear engineering because the use of nuclear energy is inevitable for our future generations. Now we inhabit the post-Fukushima era. Under this altered circumstance, the center focuses on the following four fields of nuclear engineering:

Field 1; Environmental safety and management after the accident
Field 2; Radiation safety and healthcare
Field 3; Safe decommissioning of the power plant
Field 4; Risk assessment/management and risk communication

An accident of a large-scale plant causes profound effects on the broad region and population. When faced with a crisis, quick decisions and actions are required. The risk information must be shared by all stakeholders. CSDRS has cooperated with domestic and international organizations and has hosted symposia, public lectures and international conferences about related safety topics for all stakeholders. Figure 8 shows a public lecture "On the Influence of Radiation to Human Health", and "5th World Conference on the Safety of Gas and Oil Industry (WCOGI2014) in Okayama. The 8th Symposium on Environment and Energy regarding safety culture and safety education was held in Okayama, Japan on November 24, 2015. The symposia were open for citizens, younger faculty and graduate students whom are encouraged to participate at these events. CSDRS is establishing an international profile through organizing conferences and symposia, hosting international visitors and visiting overseas institutions.

 

Figure. 8 “On the Influence of Radiation to Human Health” and “5th World Conference on the Safety of Gas and Oil Industry (WCOGI2014)

3. Building on Mutual Strength for Safety Culture

“Safety culture” is the word proposed by IAEA after the Chernobyl accident; they stated that “there was a lack of safety culture” at the accident [7]. At chemical plants in the 1980’s, some serious accidents occurred included Bhopal accident (India 1984). After severe accidents people realized the necessity of safety planning and strict regulations. Many accidents are very complex and unexpected because the accidents don't follow the safety analysis and accident planning that has been prepared for in manuals and procedures. Protecting and keeping our environment safe should always be a top priority of training and collaboration. We all have a responsibility to protect or minimize the impact on our society from accidents/disasters. On an individual perspective, every person is anxious to return home from work in the same condition they arrived at work. We need continuous improvement to sustain the safety and security of life. Due to the Fukushima accident the political situation of the use of nuclear energy is truly confusing in Japan. Safety Culture must be rebuilt for all stakeholders under this circumstance.

All USA power producing nuclear power plants are regulated and assessed on their nuclear safety culture. Analysis has been completed recently examining the relationship between safety culture and a diverse set of performance measures that focus on the overall operational safety of nuclear power plants [8]. Morrow measured organizational safety culture by the same 9 safety culture factors as listed previously. The results from Morrow’s analysis provided evidence that safety culture is correlated with concurrent measures of safety performance. This is an example that safety culture can also be an indication of better operational and plant performance as well.

3.1 Common Problems

In Japan, recovery from the Fukushima accident is a keen issue. The final and most difficult problem is the radioactive waste disposal. Reducing the negative heritage of nuclear use and acquiring safety for inhabitants and decontamination workers are needed immediately. This work must also be performed in the context of safety culture being a top priority. In addition, restructuring disaster-resistant nuclear facilities is ongoing. Before the Fukushima accident and now the primary social concern is how to reduce the emission of carbon dioxide. Worldwide energy crisis and increase of worldwide environmental issues are common problems all over the world. Nationwide shortage of professional engineers in nuclear industries and related fields is of increasing concern. Thus seeking solution for these issues, collaborative works assume a key role. At the same time, we have to remember that public acceptance is essential for nuclear use. These issues, if released, could have a major impact on workers, surrounding communities, or facilities. The consequences of our collaborative work for safety culture have significant life-threatening, environmental, legal and financial implications.

3.2 International Networking and Collaboration

Both the University of Utah, UNEP and Okayama University, Center for Safe and Disaster-Resistant Society have successfully contributed to the progress of cooperating with domestic and international organizations. The exchange of students and researchers related to the present effort have led to positive result of interactions, networking and synergism. This should be strengthened through scientific exchanges of both students and researchers. It has been shown that multidisciplinary discussions on the issues to nuclear power and safety culture are very fruitful and promote common understanding. The implementation of safety education in US and Japan is to take the strengths of each organization to make a synergistic working environment. The objectives and purposes of international collaboration of safety culture, for example between The University of Utah and Okayama University is following, sharing experiences, creating partnership opportunity, development safety education contents.

Both faculty and staff members from UNEP and the Center for Safe and Disaster-Resistant Society have travelled to each other's facilities and shared their lessons learned and ideas with the other group students. This cross-pollination of ideas and thoughts on safety culture helps to keep both programs leading out in their students become safety culture ambassadors to share the safety culture vision in any industry that they are performing work in.

4. Conclusion and Future Work

The synergy and collaboration between two different programs and cultures has been enlightening and innovative. Best practices and ideas are shared with success and resulted in international symposia on engineering safety cultures where both parties presented their views, practices and outlined the challenges and paths forwards.

We invite the community to join our successful efforts in developing, and sustaining strong nuclear engineering safety culture training and educations.

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Poster

BRIDGE- THE FIRST NUCLEAR EDUCATION ERASMUS+ PROJECT

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ABSTRACT

Classically, a BRIDGE has two starting points. Or two ends. We considered these two points to be on the one side a person, a trainee, and on the other side a company that is looking to hire him. The project was conceived in such way that the BRIDGE is representing the educational institutions that adapt their curricula according to end user's needs. Generally, these needs are expressed in a set of knowledge, skills and competences (KSC) required by a specific job profile. On the other hand educational and training institutions must shape a person according to labour market needs. Labour market is in a continuous change thus a permanent link between end user, higher education institution and training centres is required. Nowadays labour market is very dynamic. This includes employee itself. Internationalization and free circulation, at least in European Union, forced education and training institution to adapt their programme not only local but at least at European level. The project itself provides a trainee a set of information necessary to find a company acting in nuclear field (to choose from several countries), to look into several job profiles and to have an idea the set of KSC is required and to look into educational programme in order to be able to choose according to its desire. For companies, the project provides a small tool that is intended for labour market analysis, for company analysis when it comes to job needs and also a small tool useful for designing their own job profiles or to choose one that is already defined according to other similar company's needs. Last but not least it provides for educational institutions the information about end user's needs so that they can adapt their curricula accordingly.

Introduction

The human resources recruiting experience shows that there is a gap between the knowledge provided by the academic institutions (expressed in ECTS) and that required by the end-user (based on the job profile and delivered in a SAT system). Usually the end-user considers that, despite ECTS proven efficiency, the academic institutions have poor and insufficient information regarding the knowledge the students and trainees have to gain and that is relevant for their future field of work. Thus, companies that hired these people developed a training process that required also a certain amount of time for an already educated person in order to make better use of each individual working qualities and potential.

Thus was shaped the idea of the Better undeRstandIng anD recoGnition of nuclEar skills and qualifications - BRIDGE which appears to be the first Nuclear Education Erasmus+ project.

In view of future implementation in the nuclear field of the European Credit System for Vocational Education and Training (ECVET) this project aims to „bridge" the exiting gap between the use by the academic institutions of European Credit Transfer and Accumulation System (ECTS) and the use by the end-users (industry, regulatory bodies, research and development entities) of the Systematic Approach to Training (SAT). Actual practice involves overlapping of topics from educational and training programs, with considerable costs in time and money.

To achieve this goal should be determined the needs for qualified personnel as well as the path and the methodology used by the academic and the training institutions to deliver specific learning outcomes (including assessment, validation, transfer and recognition). First objective of the project is to determine the institutions or companies who are recruiting undergraduate/graduate students to enrol as trainees. Therefore were chosen partners from industry (Energonuclear- Romania), research (Josef Stefan Institute-Slovenia) and training (Tecnatom-Spain). Next objective is to determine how the existing in higher education (at University Politehnica Bucharest-Romania) curriculum satisfies the nuclear industry needs expressed in terms of job profile. Therefore was proposed a methodology regarding the criteria to be taken into consideration when the needs for qualified personnel are evaluated. Moreover, each partner institution analysed the UPB curriculum and presented a projection of the desired pattern of academic curriculum shaped to its necessities.

The expected project outcomes are the continuous analysis of the teaching methodology, the evaluation of the training techniques, the accordance between the curriculum and course contents with the specific job requirements, giving recommendations on adapting the curricula and other activities to the end-user needs. They should be foreseen as an important phase in making first steps towards SAT implementation and modernization of the education and training programs existing in higher education institutions. As impact, it is expected that this methodology/approach could lead to a better management of human resources on a longer term, a more efficient manner in providing necessary and useful information to future employees and less money to invest in human resources in order to obtain the desired qualifications.

Who wants me?

The two main targets of the project are represented by the trainee and the hiring company. First major questions for a trainee/student, for example, is where to find a job after graduation. During the project implementation partners analysed the situation in Romania, Slovenia and Spain and provided a full list of companies that are offering job positions in nuclear field. The list can be found at www.bridge.pub.ro As an example, it can be seen that according to Table 1, only in Romania one can chose from at least 10 companies offering job positions in nuclear field. The list of institutions presents only the biggest companies.

No.	Institution name	Activity/field of work	Estimated Number of nuclear positions
1	Cernavoda NPP	Nuclear Power Plant	2250
2	S.C. EnergoNuclear S.A.	Nuclear Power Plant constructor	25
3	Nuclear fuel manufacturing plant FCN- Pitesti	CANDU fuel supplier	193
4	SN “NUCLEARELECTRICA” SA	State owned company/ generation of electrical and thermal power, and manufacturing of nuclear fuel	20
5	Nuclear Technology and Engineering Center (CITON)	Nuclear Engineering & Design	196
6	National Commission for Nuclear Activities Control (CNCAN)	National Authority	137
7	Ministry of Economy - Nuclear Agency and Radioactive Waste	National Authority	15
8	Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH)	Nuclear R&D institution	
9	National Institute of Research and Development for Cryogenic	Nuclear R&D institution	34

	and Isotopic Technologies - ICSI Rm. Vâlcea		
10	RATEN-Institute for Nuclear Research -Pitesti	Nuclear R&D institution	- Estimated to be a few hundred

Tab.1. List of important institutions acting in nuclear field, in Romania

What does a company want from me?

The second dilemma, after finding out who are these companies that he or she will address is what they expect from a specific position. Every company has specific job positions. The answer for the question “what does a company from me” is very complex. It depends on the company profile, it depends on level of company involvement in a specific topic, it depends on responsibility the company requires for a specific job, it depends on what the company wants to focus on with respect to that specific job position. All these are concentrated in a so called job description. As seen in Example (job position provided by Energonuclear S.A-company in charge of Units 3&4 for Cernavoda Nuclear Power Plant) from Table 2, a job description contains the full set of knowledge, skills and competence needed to be able to attend that position. In general Institutions acting in nuclear field have both, regular and so-called “nuclearized “types of job profiles. The regular job profiles are considered to be the position an individual can attend even if he or she received no specific nuclear training. These positions can be found in any other industry. On the other hand, a “nuclearized” position refers to a position specific to nuclear industry or even a position adapted from any other industry to the nuclear field.

In order to qualify to attend a position related to nuclear field an individual must attend specific training program in order to achieve a level of competence making the respective person suitable for that position. One other key aspect is that in nuclear field safety and security (in particular related to nuclear industry) requires special attention and dedicated training.

Any occupational category a “nuclearized” job position has it is based on specific knowledge, skills and competences (KSC) an individual must have or acquire in order to access that position. For each KSC there are a set of topics to be addressed and how *deep* the level of competence needs to be. This is *measured* with the help of European Qualifications Framework (EQF). According to [1], EQF acts as a translation device to make national qualifications more readable across Europe, promoting workers and learners' mobility between countries and facilitating their lifelong learning. The EQF aims to relate different countries' national qualifications systems to a common European reference framework. Individuals and employers will be able to use the EQF to better understand and compare the qualifications levels of different countries and different education and training systems.

EQF has a scale from 1 to 8 and according to [2], each of the 8 levels is defined by a set of descriptors indicating the **learning outcomes** relevant to qualifications at that level in any system of qualifications. In the context of EQF, knowledge is described as *theoretical and/or factual*. In the context of EQF, skills are described as: *cognitive* (involving the use of logical, intuitive and creative thinking); and *practical* (involving manual dexterity and the use of methods, materials, tools and instruments). Competence is described in terms of*responsibility and autonomy*.

Job Title : System Engineer
Phase: NPP in construction
Occupational Category: Professional
ROLE/FUNCTIONS :

Participate in engineering activities for U3-4 (identifying and applying engineering and safety legal requirements for the design and construction of nuclear units). Participates in developing technical specifications for the procurement of services and construction works U3-4 Collaborates with the procurement specialized compartment in elaborating the specific documentation and participates in the evaluation and negotiation committees. Participates in pursuit of the contracts concluded by EnergoNuclear in its own activity domain. Participates in solving all the issues from the regulatory and coordination bodies in the activity field. Participates in the approval for documentation involving various engineering and constructions aspects. Participates in the meetings of the working groups for the activities specific for the Engineering Department.	
JOB REQUIREMENTS	
Knowledge (Experience)	**Knowledge (Experience)**
Basic studies: Higher Technical Education	7
Knowledge of Legislation / Regulations	2
Quality assurance management	3
Nuclear Safety Culture	3
Knowledge of LWR and / or CANDU type NPP: nuclear reactor theory, nuclear engineering, Control and command of CANDU type reactors, Thermalhydraulics, Heat and mass transfer, Radioprotection	5
English proficiency	4
Contract Planning and Management	2
Skills	**EQF level (1-8)**
Engineering specific computer codes	3
Planning activities	2
Technical specification/documentation for various tasks	2
Communication techniques: negotiation, presentations, reporting, correspondence	4
Microsoft Office suite	5
Competences	**EQF level (1-8)**
Discretion and confidentiality	6
Analytical thinking	6
Communication skills	4
Stress tolerance	4
Organized with the capability of structuring information	5

Tab.2. Job description-EXAMPLE

Where do I get the necessary KSC from?

Nuclear industry specific knowledge, skills and competences can be obtained if an individual attends courses, training programs or classes offered by dedicated institutions able to provide them. These institutions are represented by universities, training centres, or any other entity qualified to provide training for nuclear specific job profiles. Usually, such training program must respect national regulations which are in general based on international regulations or recommendations. Universities from European Union (EU) countries adopted in 1999 a unified training scheme the so called Bologna Process. The Bologna Process is a collective effort of public authorities, universities, teachers, and students, together with stakeholder associations, employers, quality assurance agencies, international organizations, and institutions, including the European Commission aimed at easier recognition of qualifications and periods of study and strengthening the quality assurance.

For exemplification purposes we present the situation in University *Politehnica* of Bucharest. University Politehnica of Bucharest(UPB), Nuclear Energy Department offers the only full scale higher education curriculum in Nuclear Engineering and in IT and Management of Power Installations, being the main provider of skilled personnel for national nuclear industry (utilities, nuclear agencies and regulatory body) since 1970. Only relevant topics were maintained.

University Politehnica of Bucharest - Educational Program for Power Engineering (BSc)

Year 1

- Mathematical analysis I
- Linear algebra
- Descriptive geometry and technical drawing I
- Numerical simulations
- Physics I
- Material Technology
- Educational Psychology
- Advanced Mathematics
- Mathematical Statistics and Differential Equations
- Engineering Graphics
- Physics II
- Programming
- Professional Communication
- Mechanics

Year 2

- Electrical Engineering Fundamentals I
- Thermodynamics I
- Fluid Mechanics I
- Material Resistance
- Electronics
- Power engineering fundamentals
- Numerical methods
- Electrical Engineering Fundamentals II
- Thermodynamics II
- Heat and Mass Transfer
- Mechanisms and mechanical parts

Year 3

- Electrical measurements
- Electrical machines and drive systems
- Thermal equipment and installations
- Electrical equipment
- Automatic Control theory
- Nuclear Processes
- Electric and thermal energy generation in thermal Power Plants
- Electric installations in power plant and power stations
- Nuclear Reactor Theory
  Dosimetry and radioprotection

Year 4

- Nuclear Power Plants
- Nuclear installation thermal-hydraulics
- Nuclear materials
- Nuclear power plants control
- Radioactive Waste Management
- Nuclear reactors engineering
- Reliability
- Nuclear power plants systems
- Nuclear security
- Experiments in nuclear reactor theory

University Politehnica of Bucharest - Educational Program for Master in Nuclear Engineering (MSc)

Year 1

- Advanced NPPs systems
- Reactor Physics and computing codes
- Nuclear materials for advanced nuclear reactors
- Dynamic processes modeling/ simulation of NPPs systems and equipment; computing codes
- Advanced numerical methods
- Nuclear safety; human factor
- Environmental impact of nuclear radiation
- Radioprotection; computing codes
- PSA; computing codes
- Nuclear Thermal-hydraulics; Computing codes

Year 2

- Nuclear legislation and regulations
- Nuclear Safety Analysis
- Nuclear Fuel Cycle – Back End

BRIDGE for companies

The project developed for companies a small tool that can help them create a new job profile according to their needs. A company can choose to define all necessary KSC from scratch with all necessary topics including the EQF level required for each topic. The tool provides the user to select first the entity type, then a position in the company, then the full KSC needed as seen in Figure 1.

Knowledge				EQF lvl
	1	Basic Studies: Higher Education in Science or Engineering (M. Sc. or Ph.D.)		8
	2	Knowledge of Legislation / Regulations		7
	3	Quality assurance management (QA/QC)		7
	4	Nuclear Safety Culture		8
	5	Knowledge of PWR reactors: nuclear reactor theory, nuclear engineering, Th		8
	6	English proficiency		5
	7	Contract Planning and Management		7
	8	Scientific computing and visualisation		5
	9		0	0
	10		0	0
Skills				
	1	Engineering specific computer codes		7
	2	Planning activities		6
	3	Technical specification/documentation for various tasks		6
	4	Communication techniques: negotiation, presentations, reporting, correspo		8
	5	Microsoft Office suite or similar software		5
	6		0	0
	7		0	0
	8		0	0
	9		0	0
	10		0	0
Competences				
	1	Independence		7
	2	Discretion and confidentiality		7

Fig. 1. Selection of knowledge, Skills and Competences-Example

On a lighter version one can choose between pre-existing job profiles. A company can select its profile, and then the foreseen position and the tool will provide the KSC as present in other analysed companies.

Remarks

Project was conceived so as to provide a BRIDGE between the academic institutions that use the ECTS system (starting with Bologna process) and the SAT approach used by companies when dealing with human resource development.

Project addresses on the one hand the companies by providing them with a very simple tool that could help define a new job position or adapt one according to their needs or market needs.

On the other hand the project's results can be used by individuals to obtain information about the companies that are looking to hire in the nuclear sector and the necessary KSC for specific job positions.

More information about the project and the results can be obtained at: www.bridge.pub.ro

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[2] https://ec.europa.eu/ploteus/en/content/descriptors-page, as of 22.04.2016

DEVELOPING MULTIMEDIA TOOLS FOR USING IN RADIATION SAFETY AND LASER PHYSICS TRAINING PROGRAMS

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ABSTRACT

Nuclear Training Centre (CPSDN), department within the "Horia Hulubei" National Institute of Physics and Nuclear Engineering IFIN-HH, is developing, since 1970, the post-secondary and post-graduate training for the personnel involved in practices with ionising radiation sources or advanced physical techniques. Nuclear Training Centre offers mainly training programs in radiation protection and radiation safety in medical, industrial and research practices (non-NPP). New challenges have arisen for us since our institute is building a new research facility ELI-NP (Extreme Light Infrastructure - Nuclear Physics) at frontiers of science, including a very high intensity laser system (2 x 10 PW maximum power) and a very intense Gamma Beam System.

Few years ago, CPSDN started a modernization process including e-Learning tools. Developing of e-Content in order to be used for computer-based training, on-line courses or as tools for dissemination of information in nuclear and lasers physics represented one of the main challenges of this process.

This paper presents some of the software applications and multimedia instruments designed, developed and implemented in our e-Learning system, in class-room training or in the website as an instrument for public education. Interactive software applications were developed as a set of modern technologies, in expansion and wide supported (Flash or HTML5, as well as jQuery Mobile and CreateJS frameworks), capable to run on desktop computers, but also on modern devices such tablets and smartphones. High interactivity tools in the field of radiological protection in medicine, safety of radioactive sources and lasers' physics have been developed.

Implementation of these multimedia tools represent a great benefit due to the fact that the need of equipment could be eliminated, especially in physics and engineering, and because phenomena at the sub-microscopic level can be modelled and intuitive illustrated in atomic and nuclear physics.

1. Introduction

In the field of teaching of sciences, but also specifically for the nuclear domain, there are continuous efforts at the international level to introduce the digital tools in the learning process [1-4]. Thus, new educational technologies are already available, but the integration of these technologies in the training process is still a challenge [5].

Therefore, it is considered that it is necessary a specific effort to ensure a greater and durable impact for digital content developing actions (e-learning, blended e-learning or MOOCs) in order to bring the scientific knowledge to the people, enabling the personnel seeking to update their knowledge, skills and abilities or just allowing to refresh them in the framework of lifelong learning [6,7].

Within the "Horia Hulubei" National Institute of Physics and Nuclear Engineering IFIN-HH, Nuclear Training Centre (CPSDN) is developing, since 1970, post-secondary and post-

graduate trainings for the personnel involved in practices with ionising radiation sources or advanced physical techniques. The Training Centre offers mainly training programs in radiation protection and radiation safety for medical, industrial and research practices (non-NPP). CPSDN has started a modernization process that includes e-Learning tools. In this context the development of e-Content suitable to be used for computer-based training, on-line courses or as tools for dissemination of information in nuclear and lasers physics, has been representing one of the main challenges of this process.
The aim of this paper is to present some of the software applications and multimedia instruments designed, developed and implemented in our e-Learning system, in class-room training or in the website as an instrument for public education.

2. Software applications on the safety of radioactive sources

There have been developed several interactive applications consisting of a set of both Flash and HTML5/JavaScript technologies (like jQuery Mobile and CreateJS frameworks) capable run on wide range of modern devices, from desktop computers up to tablets and smartphones.

Application "Testing of sealed radioactive sources"

This application (Fig. 1) reflects the system of sealed sources classification based on utilization conditions. Sources are tested in order to demonstrate that they could be used with no risk of capsule damage and spread of radioactive material under normal operating conditions.

Fig. 1. Application "Testing of sealed radioactive sources"

Tests are developed based on operating technical conditions and source is classified function of its suitability with this test, according to ISO 2919 standard (Temperature, Pressure, Vibration, Puncture).

Five tabs on the screen which open different scenes at a click. Trainees could select one of the several intensity levels and tests the source. A contaminometer is used for monitoring; it indicates the increase of radiation dose rate in case of capsule damage.
User has a sealed radioactive source in order to be virtually tested for evaluation of the safety requirements and classification of the source. Each test can be applied in several degrees of severity. The failure of the procedure related to the classification of a source under a certain category is indicated by the apparition of a fissure on source capsule (Fig. 2) and hence the leakage of radioactive material, respectively by the increase of dose rate indicated by the contaminometer (by almost one order of magnitude).

Fig. 2. The class numbers of the sealed source

In the end, the class numbers indicating the classification of radioactive sealed source according to ISO 2919 could be read (Fig. 2).

Application "Attenuation of ionising radiation"

The attenuation of X-rays and gamma rays in matter is quantitative and qualitative illustrated by an interactive application (Fig. 3), respectively the attenuation of the ionising radiation beam through a substance taking into account the exponential law of photon radiation attenuation. User could select the type of material (water, concrete, lead) and he could continuously modify its thickness, revelling the Half Value Layer (HVL). The result is correlated with the diagram of radiation intensity as a function of thickness, I = f(x).

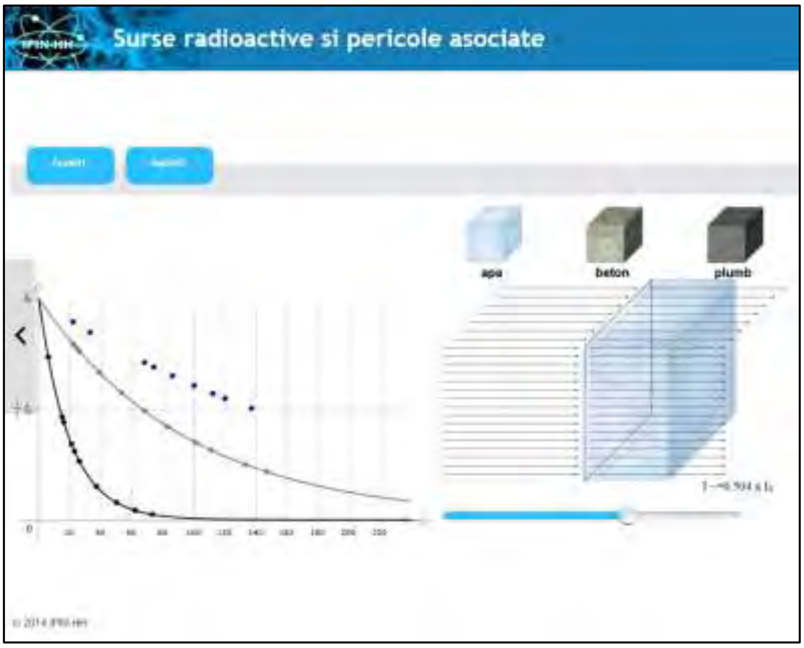

Fig. 3. Application “Attenuation of ionising radiation”

Application “Finding a lost source”

The aim is to find the position of a radioactive source based on three measurements (by triangulation method), using a radiation detector (Fig. 4)

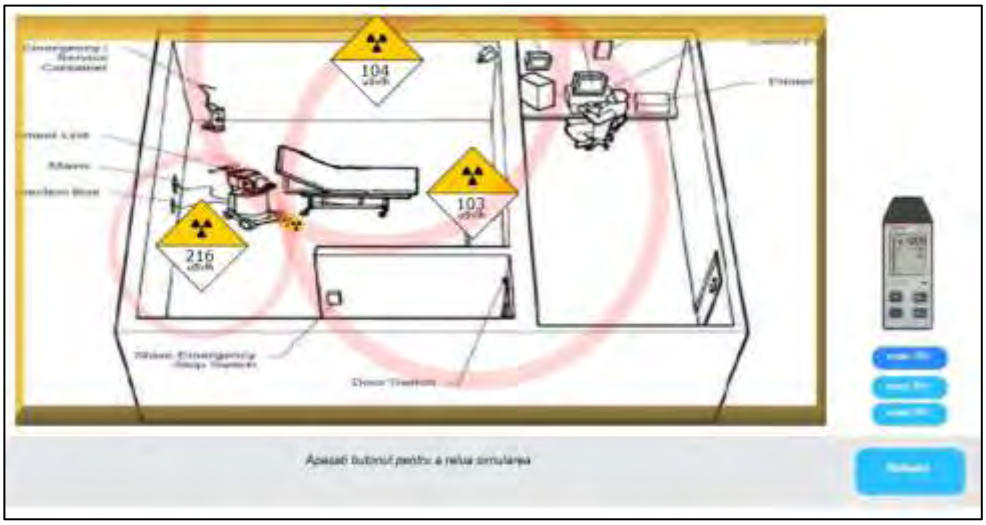

Fig. 4. Application “Finding a lost source”

In this application user could determine the position of a lost source (with a known activity) by measuring the dose rate in three different points at such a distance that he could not suffer a significant “irradiation”. Error in measuring the dose is also simulated and settled by the user (hence the inaccuracy of determination).

This application could successfully enough replace costing and radiological unsafe practical exercises.

3. Software applications of laser physics

New challenges have arisen for us since our institute IFIN-HH is building a new research facility ELI-NP (Extreme Light Infrastructure - Nuclear Physics) at frontiers of science, including a very high intensity laser system (2 x 10 PW maximum power) and a very intense Gamma Beam System.
Some highly interactive modules have been implemented in the online platform as a form of basic course on lasers physics and their applications, with a view of enhancing information and, implicitly, public acceptancy by presenting in an easy understandable way for people having secondary education level.
For each application the text is spread on several pages in the following order: scientific text, from abstract to concrete (interactive resource) and on the last page the operating instructions for the interactive resource.

Application "Population inversion. Laser effect"

Software application (Fig. 5) allows the user to understand macroscopic phenomena appearing at laser radiation emission in parallel with illustration of microscopic phenomena. Thus user interacts with the system and could notice that, by applying an external stimulation (pumping) to certain types of systems of atoms, it could appear situations when a higher energy level is more populated than a lower energy level. Subsequently, by aligning the resonant cavity mirrors, it is obtained the stimulated emission by decaying of the atoms from the higher energy level and so LASER effect appears.

Fig. 5. Population inversion. Laser effect

Application “Laser Radiation Properties”

This interactive application illustrates the properties of the laser radiation: intensity, monochromaticity, coherence, directionality (Fig. 6). User could control system states and follow their influence on the properties of a laser beam comparative with one issued by a conventional source.

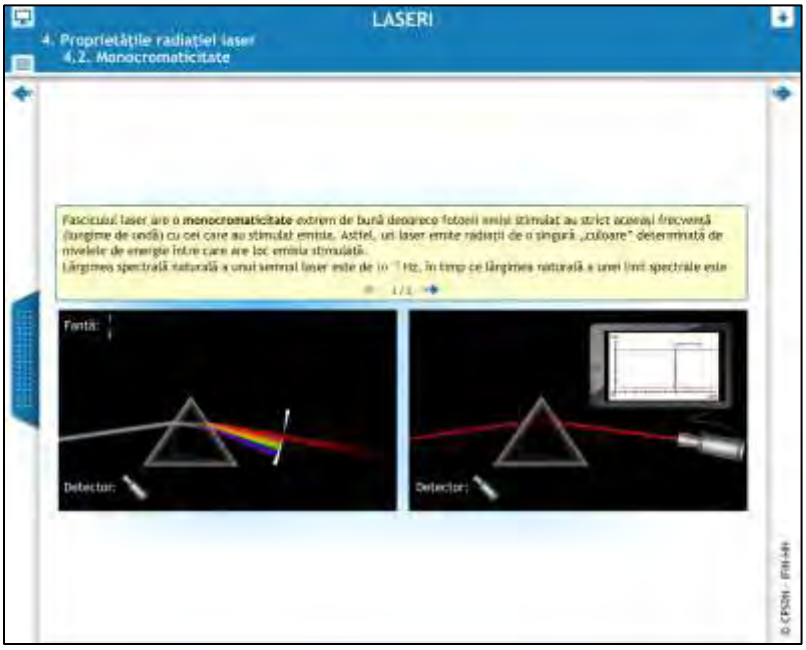

Fig. 6. Laser Radiation Properties

Video “Laser with Nd:YAG”

It was realised an educational video (Fig. 7, 8) which presents in a tri-dimensional way the model and operation of a Nd:YAG Laser. There are presented the active components of a laser with solid state and it is made the transition from the laser operating microscopic principles to the functioning of a real laser. So this movie presents:

- exciting atoms, population inversion and stimulated emission
- laser medium
- pumping system
- resonant cavity
- optical control systems.

Fig. 7. Video “Laser with Nd:YAG”

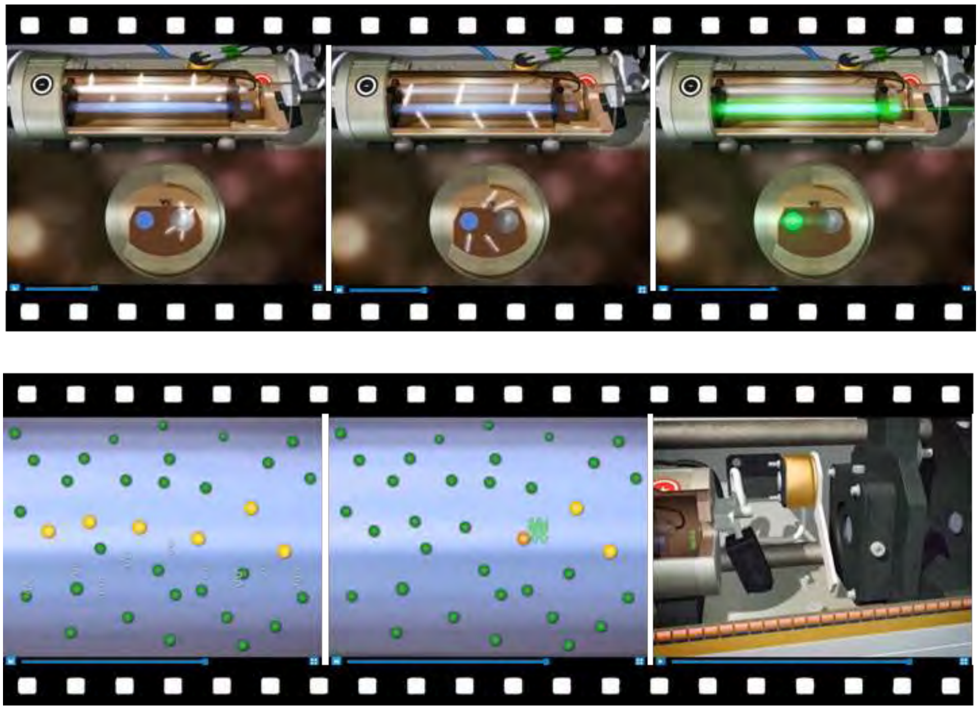

Fig. 8. A Glimpse of Video “Laser with Nd:YAG”

4. Conclusions

Developing of digital educational content is a complex activity that requires in general a well-prepared multidisciplinary team in order to elaborate the scenarios, storyboards, instructional design and to achieve actual the software applications [4, 8].
Implementation of these multimedia tools represent a great benefit due to the fact that the need of equipment could be eliminated, especially in physics and engineering, and because phenomena at the sub-microscopic level can be modelled and intuitive illustrated in atomic and nuclear physics.

5. Acknowledgements

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The Risk Perception measure, prior to the construction of a facility's services nuclear medical, in a potentially exposed population of Argentina.

Importance of the scientific dissemination.

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ABSTRACT

The initial objective of this project was to make a disclosure and essential information for the population in general, ionizing radiation and biomedical technologies and their applications in the Health Care Area (HCA), as also for their safety to the environment, workers and the population. But in the course of the same, we believe successful to measure of the risk perception prior to instances of such popular outreach to somehow measure the impact of the same for this population, and the way in which socialized training can help reduce fear or prejudices towards the use of ionizing radiation, for this type of facilities or associated radiant sources in their applications in HCA, as also for their safety for environment, patients, workers and the neighbouring population or public. Be made for this reason, dissemination tasks at the level of the population in general, phenomenology and nature of radioactive substances and the different uses of radiant sources, their potential benefits and risks arising from applied in health care, diagnostics purposes and/or treatment. Among other types of information communicated in elemental form normal equipment and instrumental performance that radioactive sources, exposing him to the community topics such as starting point on the subject, on which were emerging, and addressing user for the purpose of clarifying doubts and deepen concepts. We planned as well, a series of 5 (five) talks of disclosure and specific information for the community in general, but before starting these, became this study diagnosis on the population, that it involves knowing the initial state of knowledge and basic beliefs about radioactive sources, in way of to compare with the further fact of intervention of the project. This issue included other everyday risks, in addition to the radioactive sources used specifically to health care situations. In addition to the data collected and generated learning materials, this project served to move fundamental basic knowledge from the University to the community, which have an impact on the formation of opinion. On the other hand, it also served to communicate related careers that they dictate in our faculty.

1. Introduction (12 pt, bold)

The risk perception is a theory that addresses what way and why the individuals who make up a population, qualified on a relative scale, major to minor or vice versa. This implies the possibility that various sources of risk appear in his life, a damage or degree of damage that will result in them and the rest of the population or the environment. People qualify and create a unconscious scale values of such risks, which can be found, with respect to the actual risk, below, equal or above expectations. Escrow the possibility that various sources of risk appear in his life, damage or degrees of damage that will result in them, and the rest of the population or the environment.
Terms of the value of the Real risk, take it as reference value by the opinion given by experts, based on the criterion of knowledge with scientific and substantiated basis with the scientific method. Every person, whether an expert or not, is influenced by the perception of risk. These different possibilities for response, comparing the perceived risk with Real risk means respectively undervalued, overvalued, or give the fair value. So the individuals of a population value in a growing or decreasing scale to one or more risks, influence a number of factors, both internal and external, as also of the time

playing them live. Some features that is known to people to evaluate unconsciously to judge a risk, even if it is very complex, are mentioned in the Table Nº 1. [4] [5].

This project item, was generated because it was considered necessary to show transparency of information on the principles of the operation of a large number of technologies related to Nuclear activities and given that an installation has been designed, planned and located under the supervision and control of the ***Comision Nacional de Energía Atómica (CNEA)*** and ***Instituto de Obra Social de la Provincia de Entre Ríos (IOSPER)***, since the beginning of 2012, in the Neighbourhood ***El Triangular of Oro Verde*** town, renames currently Centro de Medicina Nuclear de Entre Ríos (CEMENER). We focus on the description of technology biomedical diagnostic images and treatments, using sources of ionizing radiation (I R) and/or radioactive sources, and their relationship with possible harmful effects on living beings, in order to arrive at a risk ratio / reasonable benefit for the population. This question was investigated, based on surveys, how to establish the State of knowledge and opinions of the people who live in the area of the catch and that seemed so dangerous this first. For that then came to light and results of the initial survey, printed material and theoretical, with basic information on the topic where exposed in colloquial language, intended for an average population. Then another shorter survey was to measure the influence of the disclosure.

1.1 Settings. (Configuring the job. Material and methods.)

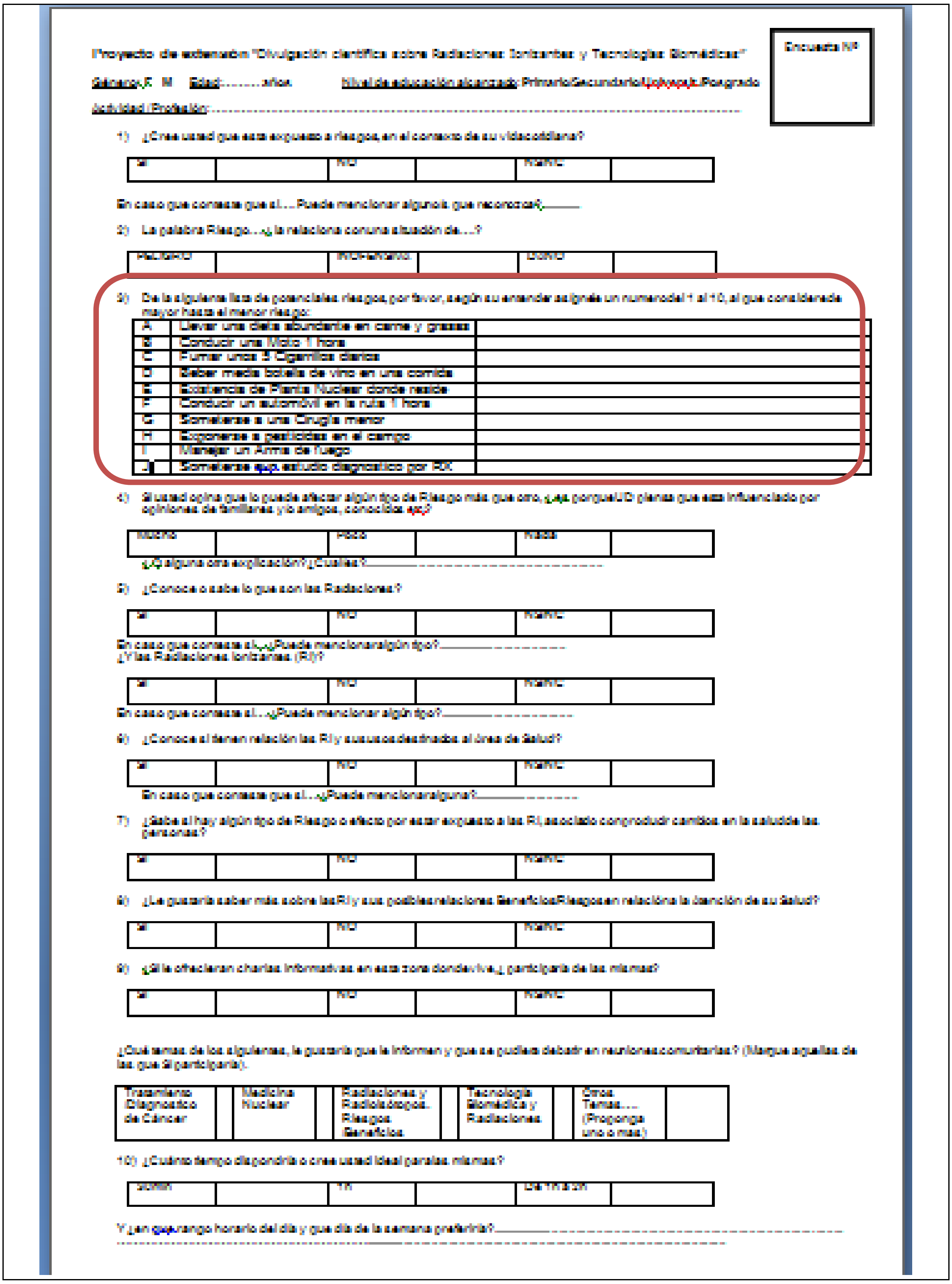
In a town of about 2500 residents of Oro Verde, site the CEMENER interlock, and before proceeding to execute tasks of disclosure for the same, we conducted surveys on a random sample, with material prepared for that purpose, it was out brief, (a single veneer and answered in an interview volunteer and staff) to enable us meet the characteristics of that population, statistically representative results (Survey can be seen in Fig. nº 1). That is also easy to analyze ours data, and then proceed to make the broadcast material. For this were made especially for the occasion, surveys as short as possible (10 questions, closed, printed on an A4 sheet veneer, as shown in Fig. Nº 1) respondents in a small personal interview, with our help, in could answer them about 7 - 15 minutes. Previously we calculate the number of surveys required minimum for a 95% confidence interval, using a statistical program (Epidat®), which threw a sample space of 124 surveys. Taking into account this calculation performed some more, after gathering several months 180 surveys (N = 180), consider to be representative. [6]. Between the material, introduced an item, the Nº 3 (which is reproduced in Fig. Nº 2), specifically to measure the perception of the risk in them. It can be concluded that afterwards, starting from the data obtained from the initial surveys, is generated a disclosure material reasonably suitable to the orders expressed therein, especially on the nature of the Radioactive Sources (RS), ionising radiations (IR), and their characteristics, on its use in the HCA and the risks for living beings, as also the benefits that can be generated for the purposes of diagnosis and treatment of diseases, which serve as assistants to generate a trial more approximate to the reality on the subject to manage the level of fear and distrust that usually cause an issue as nuclear or similar sites. Among other issues of disclosure material, explained the basic empirical measures of radiation protection that may be the general public and workers in these areas in particular, given the potential risks for IR.[1][2]. Disclosures and printed with information-sharing were institutions of the town. In all instances, we declare that our relationship with the subject, not involved interests relationship, between the parties. To analyze the results of the surveys it transferred to spreadsheets Excel®, allowing us to measure both in qualitatively as quantitatively many opinions and in particular mode psychometric fear to specific dangers part of the population. Of those surveyed, general information were rescued and that these people would be interested in participating in the tasks of disclosure mentioned. Within questions, it was our interest to compare different risks, including the Nuclear issue and the RI, which in turn can be compared with official statistics and the opinion of experts in risk management. [2][3]. For example, how many deaths have happened in place traffic, this is a Causal agent that inflicts a certain level of damage, where the level of damage established can be death or also can be other consequences, such as amputations, disabilities, and others. These numbers, which speak of retrospectives facts, are called "Real risk", reflecting the relation cause-effect in a certain period of time, at some level, with regard to a number of population and other variables that could also be explicit. [3][4]. The measure of the perception of risk in this population, analyzed from the collected responses in the mentioned point Nº 3 of the cited initial survey (see again Fig. Nº 2, the detail of the risks). This list was explicitly added the nuclear risk, as well as other different known dangers include, where some of them are the source of some of the many causes of death in Argentina currently. Such information was processed in the following way: introduced the individual information that each respondent had performed, transcribing according to their knowledge or beliefs, the ten (10) different proposed risks, from major to minor, enumerating them 1 to 10. In an Excel® table, each risk is awarded a letter from A to J, in a row, whose weighting by persons represented one in every column (see Table Nº 2), thus appearing in each row that represents a person, the ordinal numbers which deduced each survey respondent in each column. We make the sum of fixed by these order numbers, we add them to each risk (A risk, risk B,.....until the risk J), and divide it by the total number of surveys (in our case n = 180). The outcome of each split sum (∑) n, define it as a the Average Index Value by Risk (AIVR), and the number calculated and rounded to two significant digits, it was used to establish the order of the perception of risk (this can be seen in the Table nº 2 y Figure nº 3). In these you can see that smaller is the value AIVR, greater is the fear of a given risk, and in our case, the fear of nuclear risk this 1st, then the 2nd use of pesticides and 3rd handling firearms, 4th smoking five cigarettes a day, 5th driving a motorcycle, 6th drive a car for an hour in road, 7th to undergo minor surgery, 8th have a diet rich in protein and fat, 9th take a plate of rays X and 10th drink two glasses of wine at a meal. As we shall see in the discussion, many of these perceptions are sub valuated, as that was in 8th place, and very few are correctly valued with regard to the Opinion of Experts or, what officer's statistics tell us, if we are to the actual leading causes of death in the Argentina today.

1.2 Figures and tables

Table Nº 1. Characteristics of the examined risks, in psychometric research.

SCIENTIFIC KNOWLEDGE AVAILABLE
THE EXPOSED SUBJECT KNOWLEDGE
ASSUMPTIONS AND BELIEFS BY PART OF THE EXPOSED SUBJECT
NOVELTY / FAMILIARITY OF THE RISK
OBSERVATION A LONG TERM CONSEQUENCES OR EFFECTS
IF THE EXPOSURE IS VOLUNTARY OR NOT
DEGREE OF CONTROLLABILITY /AVOIDABILITY
LETHALITY OF THE CONSEQUENCES
FEAR THAT PRODUCES THE POTENTIAL CATASTROPHE

Fig. Nº 1: **Image of the complete survey. Just 10 points in a personal and anonym survey, waiting for information about our objective of the actual level of knowledge to the people of the Town of Oro Verde, and promote a Divulgation of Nuclear affaires.**



Proyecto de extensión "Divulgación científica sobre Radiaciones Ionizantes y Tecnologías Biomédicas"

Encuesta Nº

Género: F M Edad: .... años. Nivel de educación alcanzado: Primario/Secundario/Universit./Posgrado

Actividad /Profesión: ....

3) De la siguiente lista de potenciales riesgos, por favor, según su entender asígnele un número del 1 al 10, al que considere de mayor hasta el menor riesgo:

A	Llevar una dieta abundante en carne y grasas	
B	Conducir una Moto 1 hora	
C	Fumar unos 5 Cigarrillos diarios	
D	Beber media botella de vino en una comida	
E	Existencia de Planta Nuclear donde reside	
F	Conducir un automóvil en la ruta 1 hora	
G	Someterse a una Cirugía menor	
H	Exponerse a pesticidas en el campo	
I	Manejar un Arma de fuego	
J	Someterse a un estudio diagnóstico por RX	

Tratamiento Diagnóstico de Cáncer		Medicina Nuclear		Radiaciones y Radioisótopos. Riesgos. Beneficios		Tecnología Biomédica y Radiaciones		Otros Temas.... (Proponga uno o mas)	

SI		NO		NS/NC	

Fig. Nº 2: **Item nº 3 of the Survey, for Perception Risks evaluation.**

3) In the following list of potential risks, please sort them according to your criterion, from highest to lowest risk, assigning each a number from 1 to 10.

A	Abundant meat and fat diet	
B	Driving on a motorcycle for 1 hour	
C	Smoking 5 cigarettes daily	
D	Drinking a half bottle of wine at lunch	

4

E	Nuclear facility where it resides	
F	Drive your car on route 1 hour	
G	Undergo minor surgery	
H	Exposure to pesticides in the Countryside	
I	Handle a fire weapon	
J	Undergoing X- Rays Diagnostics procedures	

Table Nº 2: **Values of systems of an interviewee in each row, for the various risks which are the columns from A to J. At the end of each column is the sum of these orders for all respondents and then calculates the Average Index Value by Risk, whose value (from smallest to the largest) corresponds to the relative order of the risk perception for this population.**

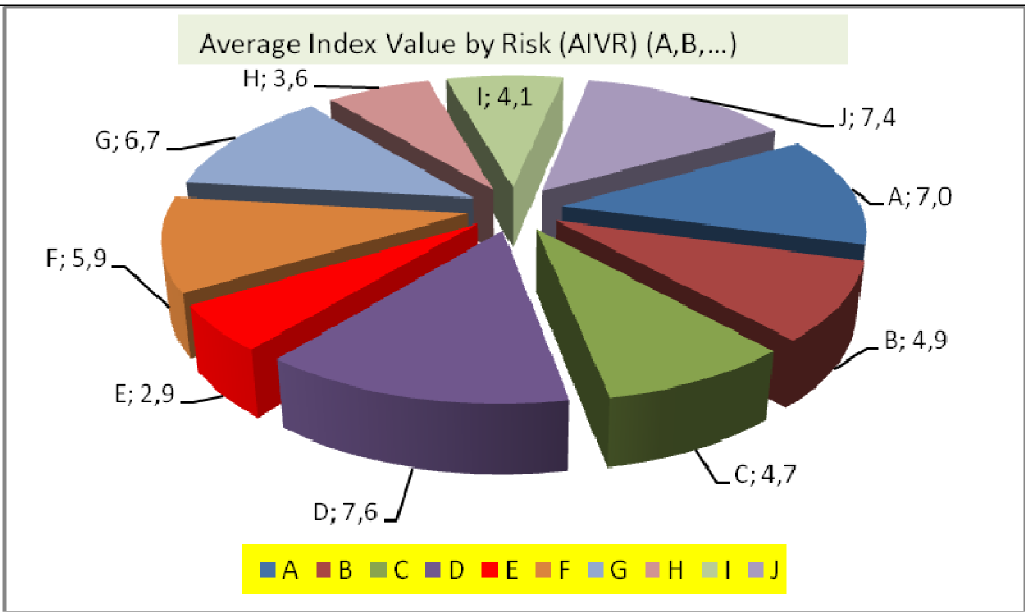
Interview Nº	Ordinance of potential risks for people who responded									
Item nº 3 →	A	B	C	D	E	F	G	H	I	J
1	9	1	7	6	3	5	4	8	2	8
2	6	5	1	9	2	7	8	4	3	8
3	8	7	3	10	1	6	9	4	2	6
4	8	10	7	6	1	9	5	2	3	10
5	7	10	4	6	3	1	8	5	2	7
6	7	3	5	8	2	4	10	9	1	6
7	6	4	5	8	1	7	9	3	2	9
8	8	9	3	10	1	7	6	5	2	7
……	……	……	……	……	……	……	……	……	……	……
177	4	5	3	2	7	6	1	8	9	10
178	6	7	3	4	5	8	10	1	2	9
179	7	4	2	6	3	8	10	9	5	1
180	3	7	2	10	6	8	5	1	9	4
Sum of each position for surveyed	**1261**	**890**	**849**	**1375**	**522**	**1069**	**656**	**656**	**741**	**1344**
Average Index Value by Risk (AIVR) (A,B,…)([Σ ni]/N= 180)	7	4,9	4,7	7,6	2,9	5,9	6,7	3,6	4,1	7,5
Relative Position of the Perceived Risk Measured	8º	5º	4º	10º	1º	6º	7º	2º	3º	9º

Table Nº 3: **Real risk and Perception of risk in a potentially exposed population (N = 180)**

Real risk position (according to experts)	**Kind of Risk**	**Description**	**Average Index Value by Risk (AIVR)**
A	1º	Abundant meat and fat diet	8º

B	2º	DRIVING on a motorcycle for 1 hour	5º
C	6º	Smoking 5 cigarettes daily	4º
D	5º	Drinking a half bottle of wine at lunch	10º
E	10º	Nuclear facility where it resides	1º
F	4º	Drive your car on route 1 hour	6º
G	7º	Undergo minor surgery	7º
H	8º	Exposure to pesticides in the Countryside	2º
I	3º	Handle a fire weapon	3º
J	9º	Undergoing X- Rays Diagnostics procedures	9º

Figure nº 3: **Graphic representation of the relative distribution of the values calculated in the table Nº 2 of the Average Index Value by Risk (AIVR).**



2. Discussions. Conclusions

When experts judged a risk that involves an activity, their responses are highly correlated with the estimation of morbidity and/or mortality annual that they can result. On the other hand, risk judged by those not skilled is sensitive to other qualitative characteristics, as for example, if the exhibition activity is voluntary or not, of their catastrophic potential, if the knowledge of the risk is controllable or not, in the way in which are made known those risks, etc. In overview the perception of the risk, it's a human, cultural and social phenomenon, which makes that ultimately underestimated the risks as they are also overestimate, which leads to expressions contradictory optimism and drama, fatalism, apathy and even some irrational fear, according to the case and fashion in the news.

This group to overturn their opinions in either direction depends mainly on the nature of the risk, known as be and at the same time if the information source is reliable or not, by who or who is controlled, which its origin is, and other factors. The result of this type of study in definitely, has become a regulator of technological development because it represents, at the social level the high degree of acceptance or rejection of great scientific advances. The result of this perceived risk, it is likely that given the impact that caused the unofficial news of the Nuclear facility in the small town, and the very quick way to build the site, without before assessing their impact on the formation of opinion, it was the proposal explanation average was the most voted because as of greater perceived risk (i.e. that risk E, or of Nuclear installation has a value of AIVR that places it in the 1st place of fear for this population in particular, and should be noted that this is diametrically opposite to what the experts would give its opinion within these proposed relative ten risks), since experts have in mind the knowledge criteria, design, legal aspects and control by national and international organizations, the philosophy of security and other elements for radiation protection resources used in facilities with radioactive sources. AIVR values for each question allowed sorting them from major to minor, on average for all respondents. According to risks experts, the risks order proposed, the order of greatest danger to minor coincide with reality, and are located in the extreme left column that can be found in the table Nº 3.

The last two risks (I, J) may be deemed to be properly valued by the public in their perception, but others such as the A, which consists of eating diet rich in meat and fats, where it should be noted that in the Argentina (and many other parts of the world also), according to official statistics, it is the 1st and leading cause of death, since it is one of the main factors in influencing the production of cardio respiratory failure, cardiovascular and brain vascular, and but for this mean population signify of the less risky for their lives or they not have afraid to continue with this type of intakes. This risk factor appears in 8th place in these surveys. The issue pesticides, which was 2nd in this scale of responses, was overvalued as risk (according to the opinion of experts), perhaps because this city is small, and is located in the countryside in the midst of cultivable areas and is also this, a theme established constantly in the media, where there are conflicts of interest. It causes other real risks, as they are deaths from accidents of motorcycles and in cars, nor inspired fear in the surveys, since these are the basis of the 2nd death. In regards to subsequent surveys and comparison with the previous, they have been exhibited in other work. [6].

As a corollary, we can conclude that a project like the one mentioned here can be very good and laudable intentions, but if it is not well connected, just a social opposition (which could be irrational even), can lead to the failure of the same and the investments made so far.

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MASTER IN NUCLEAR ENGINEERING IN BARCELONA: SINERGY AT INDUSTRIAL AND ACADEMIC LEVELS

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ABSTRACT

The Master's degree in Nuclear Engineering (MNE) from the Universitat Politècnica de Catalunya (UPC) is now in its fifth edition. The Programme is born from the alignment of objectives of Academy and Industry. Endesa and UPC are committed to maintain and nurture the know-how in nuclear engineering education in a complex social and political context. The Master has a clear industrial vocation and aims to prepare competent engineers for the Nuclear Industry. The Master's 90 credits (each credit implies 25 hours of student's work) are divided into one year of courses (60 credits) and one semester of internship plus master thesis (30 credits). A large portion of the master contents is delivered as Problem or Project Based Learning. In general, active learning and team work activities are thoroughly used so as to help students achieve the learning objectives and acquire a number of soft skills valued by Industry. From its beginning the MNE has had the implication of a large part of the Spanish Nuclear Industry, along with research institutions and the Spanish Regulatory Authority. The participation of professionals external to the University in the definition and revision of the Programme is one of MNE's assets. Companies and external institutions participate actively in the master providing lecturers for specific topics, accepting students in internships and organizing technical visits. Lecturers from companies (ANAV, AREVA, Endesa, ENRESA, ENSA, ENUSA, Nuclenor, Tecnatom and Westinghouse), research institutes (CIEMAT) and the Spanish Regulatory Authority (CSN) are all participating in teaching at the Master. Around one half of the lectures are delivered by professionals external to UPC. The master is completely taught in English, to attract international students and to train Spanish students to compete in an internationalised labour market. MNE is part of EMINE, the European Master in Nuclear Energy (European Institute of Technology, KIC-InnoEnergy). Since 2014 a double degree exists in the Barcelona Engineering School with the official Master in Industrial Engineering, MUEI. Having in the same classroom EMINE and MNE students creates a good working atmosphere, while allowing the future engineers work in a multicultural and international environment. The double degree MNE-MUEI has been useful to attract good engineering students to the MNE. After five editions, the master is firmly stablished and the alumni value it positively.

1. Introduction

Universitat Politècnica de Catalunya · BarcelonaTech (UPC) [1] is a public institution devoted to higher education and research, specialized in the fields of architecture, engineering and technology that produces professionals competent to tackle present and future challenges.

In total, UPC's 22 schools scattered among 7 cities, offer more than 60 BSc programs and a similar number of MSc programs, 21 of these master programs are taught in English. The UPC is running more than 50 PhD programs.

One of the MSc programs completely taught in English is the Master's degree in Nuclear Engineering (MNE), which is now in its fifth edition [2]. This program is closely related to the PhD program in Nuclear and Ionizing Radiation Engineering [3].

UPC has more than 30’000 bachelor’s and master’s students, and it ranks among the largest universities in Spain. With more than 2’300 PhD students and near 3’000 teaching and research staff members organized into more than 200 research groups and about 50 research centers, the R&D potential of UPC has placed the institution in a very good global position. More than 2’300 articles published in scientific journals were authored by UPC’s staff in academic year 2014-2015.

One of the education centers of UPC is the Industrial Engineering School of Barcelona (ETSEIB) [4]. ETSEIB has more than 3’000 students, more than 400 teaching staff and more than 240 people working in administration and support tasks. The School was created in 1851; in 1971 it was one of the Schools that joined to conform what is now the UPC. Engineering education at ETSEIB encompasses a broad spectrum: automatic control, bioengineering, chemistry, computer science, construction, electric engineering, electronics, energy, management, materials, mechanics, transport, etc.

Since its beginnings, the Industrial Engineering School of Barcelona has had strong links with the Nuclear Industry. The present building of the School hosted a research nuclear reactor that was in operation between 1963 and 1977 (see Figure 1). Nuclear education had a strong presence in the syllabus of some of the majors within Industrial Engineering (Energy Technologies, Electricity and, to a lesser extent, Chemical Engineering) until the beginning of the XXI century, when study plans were remodeled and nuclear lose grip.

Figure 1. The experimental nuclear reactor building at the ETSEIB (left and center). Recent images of the School (right); the bottom one shows the new building for laboratories and offices erected where the reactor stood in the past.

In 2005, adopting the name of the decommissioned experimental reactor, the Argos Chair of Nuclear Safety and Radiation Protection was created under the auspices of the Spanish Regulatory Authority (Consejo de Seguridad Nuclear, CSN [5]). The Chair provides grants and economic support to research and education within its scope.

In 2010 Endesa [6], the largest nuclear plant operator in Spain, approached UPC with the aim to start defining a future Master in Nuclear Engineering in Barcelona. The program of the master was defined with the contribution of professionals from industry, the CSN and research and academic institutions. Early in 2011 the Program was submitted to the National Agency for Quality Assessment and Accreditation of Spain (ANECA) for verification. In March same year a Memorandum of Understanding UPC-Endesa was signed, by which Endesa committed to sponsor the Master. In October 2011, the first edition of the Master started. In 2015 the Program was accredited by ANECA.

Since its beginnings, the Master's degree in Nuclear Engineering (MNE) is embedded in EMINE [7], the European Master in Nuclear Energy (European Institute of Technology [8], KIC InnoEnergy). Part of the academic program of the MNE is offered as well in the framework of EMINE. The students of this European master choose between UPC and KTH (Sweden) for their first year and then move to France (Grenoble INP or ParisTech) for their second year [9].

Besides EMINE, the UPC/ETSEIB is involved in other masters within KIC InnoEnergy, mainly MSc RENE (Renewable Energy), of which UPC is assuming the direction, and MSc SELECT (Environomical Pathways to Sustainable Energy Systems), but as well MSc SENSE (Smart Electrical Networks and Systems) and MSc Energy for Smart Cities.

Since 2014, a double degree exists in the ETSEIB with the official Master's degree in Industrial Engineering (MUEI). In two and a half academic years students can get the double degree MNE-MUEI (obtaining a MSc in Industrial Engineering in Spain is equivalent to obtaining a Mechanical Engineering MSc in other countries).

After five editions, the master is firmly stablished and the alumni value it positively.

2. Learning objectives. Courses.

The Master has a clear industrial vocation and aims to prepare competent engineers to assume managerial and technical positions within the Nuclear Industry, which demands professionals able to work rigorously, accordingly to the Safety Culture, imbued of a high sense of responsibility, and at the same time able to work in an international context, within transcultural teams and in a continuously changing environment.

The MNE program has been designed to help students:

- Understand the theoretical and practical fundamentals of nuclear engineering.
- Acquire a clear vision of the nuclear fuel cycle, from uranium mining to the management of spent nuclear fuel.
- Comprehend the lifecycle of the different installations, from the erection to the decommissioning of a nuclear facility.
- Gain a deep understanding of regulation and apprehend the principles of nuclear safety.
- Develop a strategic view of the nuclear industry and the ability to formulate problems and to make decisions.

The Master's 90 credits are divided into one year of courses (60 credits) and one semester of internship plus master thesis (30 credits). Each credit implies 25 hours of students' work, be it in the classroom, in the laboratory, in a field visit, before a computer, or reading their notes when preparing for an exam, to mention some of the activities. Table 1 gives an overview of the distribution of the credits.

In order to help students gain the competences needed to manage the kind of projects developed in the industry (material supply logistics, plant safety and technical management), an important part of the contents of the MNE are organised in the form of Problem and Project Based Learning. The courses and their respective allocated credits are listed in Table 2. Figure 2 illustrates the temporal organization of the contents with an indication of the transversal character of the two Course Projects.

MNE is completely taught in English, to attract international students and to train Spanish students to compete in an internationalised labour market.

Table 1. Structure of the MNE programme.

Type of Subject	Credits
Required courses	46.5
Elective courses	13.5
Internship	15
Master's Diploma Thesis	15
TOTAL	90

Table 2. Credits allocated for the different courses.

Courses	Credits
First Semester	
Fundamentals of Nuclear Engineering and Radiological Protection	8
Reactor Physics and Thermal-Hydraulics	7.5
Systems, Components and Materials	6
Fuel Cycle and Environmental Impact	5.5
Course Project 1	3
Second Semester	
Regulations and Safety	5
Management of Nuclear Power Plants	8.5
Elective subjects	3 x 4.5
Course Project 2	3

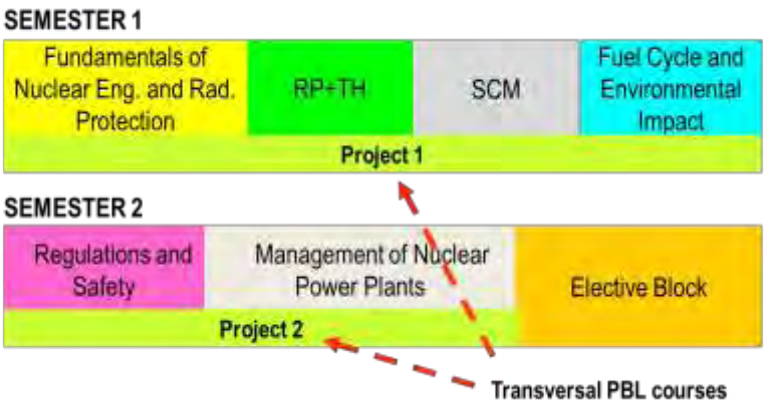

Figure 2: Distribution of the curriculum in semesters.

3. Institutions involved in MNE

This Master's degree in Nuclear Engineering was born from the alignment of objectives of Academy and Industry. ENDESA and UPC, committed to maintain and nurture the know-how in nuclear engineering education in a social and political context that makes this task difficult, joined efforts in the design and in the development of the contents of this high education program.

Endesa is the largest electricity company in the Iberian system and the major nuclear operator in Spain, with 47% of the total installed capacity. Endesa is now a part of the Enel Group, one of the world's largest utilities.

Because of its penetration in the Spanish Energy System, Endesa has eased the path for MNE in order to obtain the collaboration of the Spanish Nuclear Industry: Tecnatom and ENUSA for instance, companies with a large implication in the master, have strong ties with Endesa for different reasons.

Industrial collaboration includes one or more of the following activities: lecturing, organization of guided visits, hosting of students for internships, guidance in the definition of the contents of the master.

The implication of a large part of the Spanish Nuclear Industry has been a reality from the beginning of the MNE project. Research institutions and the Spanish Regulatory Authority have made important contributions to it as well. The participation of engineers, technicians and researchers external to the university in the definition and revision of the programme is one of the most valuable MNE’s assets.

Endesa makes it possible the attendance of MNE students to an important annual event of the Spanish Nuclear Society in Madrid (the Seminar on Operating Experiences and Perspectives, where the Spanish NPPs managers explain the operation of their plants during the previous year), by means of sponsoring the simultaneous translation of the event into English. To take advantage of the trip to Madrid, Endesa invites the students to visit its Headquarters, where students have the opportunity to exchange some words with the managing director of Endesa’s Nuclear Division and a guided visit is arranged to the Generation Control Center (Figure 3).

Figure 3. Left: Seminar on Operating Experiences and Perspectives (Spanish Nuclear Society) in Madrid in 2015. Right-bottom: visit to Endesa Headquarters the day before the Seminar. Right-top: visit to the Generation Control Center during the visit of 2016.

Endesa and ANAV [10] (the operator of Ascó-1, Ascó-2 and Vandellòs-2 power plants, all of them PWR, in the vicinity of Barcelona, owned mainly by Endesa) provide lecturers for specific topics in the course on Management of Nuclear Power Plants.

The list of companies includes: Nuclenor [11] (a company participated by Endesa that operates a BWR plant in Santa Maria de Garoña), ENUSA [12] (a publicly traded Spanish company for design, manufacture and supply of fuel), ENRESA [13] (a public company in charge of the safe management, storage and disposal of the radioactive wastes produced in Spain), ENSA [14] (a State owned company specialized in the manufacturing of heavy equipment), TECNATOM [15] (advanced engineering), IDOM (engineering company), Westinghouse and AREVA. These companies participate in different ways, either facilitating that their professionals lecture some specific topics, opening internship positions, or offering guided visits to their facilities (see Figure 4).

Figure 4. Images of some of the visits of the MNE students to industrial facilities. Top (left-to-right): Vandellòs-II NPP, Tecnatom Headquarters, Vandellòs-I graphite-gas reactor being decommissioned by ENRESA. Bottom (left-to-right): ENSA factory in Santander, ITER site in Cadarache, José Cabrera NPP being dismantled by ENRESA.

The list of external participants includes lecturers from CIEMAT (the public major Spanish research centre) [16], who lecture in the area of structural materials for nuclear plants and material degradation, but as well in other topics related with the activities of the centre, like neutronics and severe accident phenomena or nuclear fusion. For the elective course on Fusion Technology, the MNE has had the support of professionals from F4E and researchers from CEA and the Max-Planck-Princeton Center for Plasma Physics.

Last but not least, the Master has the invaluable collaboration of the Spanish Regulatory Authority (CSN). Technicians from this institution lecture some topics related to Nuclear Safety and Regulations. Moreover, the Argos Chair, sponsored by the CSN, offers fee waivers to the students

4. Learning methodology

To achieve meaningful learning, learners must face realistic situations, similar to those encountered in the workplace; they have to apply their knowledge to address problems whose solution requires making decisions. For this reason, active learning methodologies and team work are thoroughly used in the master. Assessment instruments and activities are integrated into the learning activities.

As mentioned above, an important part of the contents of the Master are addressed within a Problem or Project Based Learning (PBL) framework, which has shown to be quite adequate in the engineering education and training.

For instance, in the last editions of the Master, the transversal project developed during the second semester (see Table 2 and Figure 2) has been a 'Feasibility study of plant power up-rating". Besides the small courses organized as projects, PBL techniques have been used, for instance, within Management of Nuclear Power Plants (MNPP), when students have been faced with the "Design of a portable system to support the operation in Station Blackout scenarios" (more details of these activities can be found in Reventós et al. [17]). These projects in the second semester are followed up by specialists from industry together with academic staff.

Design and development of engineering assignments are key actions of continuous improvement activities carried out within MNE. The starting point, implemented since the very beginning in 2011, aimed to be as close as possible to actual engineering activities, e.g. analysing the suitability of the performance of any interface, designing a system, or specifying a component.

The exercises prepared following this general guideline were studies involving all the steps needed in design activities. Concepts like Design Basis, Reference Documentation or Traceability were reinforced by its use. The review of lists of systems in order to establish the impact of any design modification on their function was usually considered in the exercise. Should the exercise involve any equipment supply, the specification for it had to be prepared by the students.

Although the general guideline is still valid, self-criticism and analysis of student's results have driven the evolution of the assignments.

Students still work in teams (3 people is the standard), but an increasing number of questions have to be answered individually. Teachers prepare questionnaires and wrap-up sessions bearing in mind the contents of other connected courses (not only MNPP). Each group works as a small technical office and, although the instructor is the ultimate advisor, leadership and making value judgments are skills often stimulated. Technical meetings and debates are simulated and practiced and the response of students is extremely positive since they really try to solve the problem that is posed. Debates are also used to develop other skills like summarizing, conducting a meeting or writing down the minutes.

One of the innovations implemented has revealed as quite efficient: a traditional exercise of “Writing a Design Basis document” is converted to “Analysing the adequacy of a given Design Basis document”. In both cases students need to analyse reference documentation provided by instructors or downloaded from internet. In the traditional exercise students used the information to prepare their own document, which usually resulted rather confused and disorganized. In this context, instructor's tasks were basically devoted either to reorganize the text or to comment on the need of concision. Under these conditions instructor's feedback was not efficient. The new format allows instructors direct the feedback to technical matters.

The master aims to ease students' transition from University to Industry. The industrial internship in the third semester is part of the strategy. Another part is the fact that towards one half of the classes are delivered by lecturers external to UPC (half of them from the Industry); this participation is more relevant in subjects of the second semester. Students' visits to industrial facilities complete the strategy.

5. Sinergies with industry

As it has already been mentioned, the participation of companies and other institutions in the master does not limit to supply lecturers for specific topics. Industrial partners offer as well internship positions that allow the students develop their Master's Final Theses (see Table 3). The Industry contributes this way to the training of the students and, over some months, benefit from the incorporation of young, motivated and skilled workforce.

Guided visits contribute to the students' approach to industrial reality. The list of visits organized with MNE students include one of the ANAV's power plants near Barcelona (in

2016, Nuclenor's Garoña power plant), the ENUSA's fuel factory in Juzbado, Tecnatom's and Endesa's headquarters in Madrid, ITER site in Cadarache, the José Cabrera NPP in Guadalajara (being decommissioned by ENRESA), three days of practices at the full scope simulator of Tecnatom in Vandellòs, the ENRESA's "Centro Tecnológico Mestral" in the site of the decommissioned Vandellòs-I NPP, and the factory of ENSA in Santander (some of them illustrated in Figures 3 and 4)

Table 3. Summary of students' internships.

	2013	2014	2015	2016*
Total graduated students	15	14	10	14
EMINE students	9	11	5	7
MNE students in internships:	6	3	5	7
ANAV	3	1	1	1
Westinghouse	1		1	
AREVA (Germany)	1			
Research centres and Universities abroad	1			3
BarcelonaTECH (PhD program)		1		
BarcelonaTECH (diverse projects)				2
IDOM		1		
ENDESA			1	
Barcelona Supercomputing Center			1	
ENUSA			1	1

* Prevision

Another important activity in this regard is the participation in the Seminar on Operating Experiences and Perspectives (Figure 3). This seminar represents the students' immersion in the real industrial world. Within the Master, this seminar is programmed as an activity of the course on Management of Nuclear Power Plants.

The involvement of Industry and the Regulatory Authority has been essential in the definition of the master's programme. The contents of the program are being continuously improved with the help of our industrial partners.

The use of active learning, PBL and team work activities all along the programme help the students not only achieve the learning objectives but also acquire a number of soft skills valued by industry. This way the master contributes to prepare the future professionals the society needs.

6. Academic sinergies

As it has been mentioned, the MNE from UPC is offered as well in the framework of the European Master in Nuclear Energy (EMINE). The program was launched by KIC Innoenergy in 2011, the same year as MNE (see Cabon et al. 2016 [9]).

In addition to the substantial grants it offers to excellent students, KIC InnoEnergy is funding EMINE directly. It allows to develop a series of activities that otherwise wouldn't be possible.

The inclusion of the MNE within EMINE has reinforced the links of the UPC with the other institutions participating in the European Programme, and has increased the visibility of UPC within the international community of higher education on nuclear engineering.

Continuous program reviews and improvements are requested by KIC InnoEnergy; this fact has forced the MNE at UPC to sharpen the saw, and has reinforced the self-demanding attitude of the master's faculty, thus improving the quality of the Programme.

In what concerns the daily development of the master, EMINE and MNE students share the classroom and courses. Having EMINE and MNE students together creates a good working atmosphere, while allowing the future engineers work in a multicultural and international environment. Besides, it somehow forces our Spanish students to use English in more situations than they would have done otherwise.

On the other side, EMINE has benefitted from MNE. The large industrial involvement in MNE was a key factor to place the European master in a very good position before KIC InnoEnergy, and helped EMINE obtain a quality label from the European Institute of Innovation and Technology.

Finally, the double degree MNE-MUEI, offered by the Industrial Engineering School of Barcelona since 2014, allows students acquire the MNE competencies and, at the same time, legal engineering attributions in Spain. MUEI duration is 120 credits (two years). Taking advantage of common subjects, internship and final project, students can obtain the double degree taking only 171 credits (that can be concentrated in two and a half years). This offer has been useful to attract good engineering students from ETSEIB to our Programme, a fact that helps improve its quality.

7. Conclusions

The Master's degree in Nuclear Engineering from the Universitat Politècnica de Catalunya was born with a clear industrial vocation. Students develop a strategic view of the nuclear industry and the ability to formulate problems and make decisions, acquire the competencies needed to manage the projects that are run within a company, and cultivate the sense of responsibility which is at the basis of the Safety Culture.

The strengths of the MNE can be summarized as follows:

- Industrial focus of the programme,
- External participation in its definition,
- Learner oriented learning methodology,
- Large tradition of Nuclear Engineering education at UPC,
- Important industrial implication in the master,
- Large share of lectures delivered by external experts
- Implication of the Spanish Nuclear Regulatory Authority (CSN),
- Technical visits to industrial facilities.

Being safety issues of paramount importance in the exercise of the profession, the collaboration of the Spanish Regulatory Authority (CSN) with ETSEIB/UPC concerning Nuclear Safety (Argos Chair) is deemed essential for the Nuclear Engineering education.

UPC is committed to the quality of education; specifically, the MNE's faculty is highly motivated for continuous improvement. In this line, among other actions, transversal and course projects are being rethought, in line with the requirements of KIC InnoEnergy [17].

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EUROPEAN MASTER IN NUCLEAR ENERGY (EMINE). WHEN ACADEMY AND INDUSTRY MEET

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ABSTRACT

EMINE master programme is an international education initiative offered by KIC-InnoEnergy under the framework of the European Institute of Innovation and Technology (EIT). Students in the programme have the opportunity to acquire an in-depth knowledge of the nuclear industry, through unique and specialised courses covering a wide range of subjects. Students choose between UPC (Barcelona) and KTH (Stockholm) for the first year and between Grenoble-INP and Paris-Saclay University (France) for the second year. Grenoble École de Management (GEM) completes the list of academic partners: students take a 3-week summer course on energy management issues after their first year in EMINE. EMINE students also benefit from the involvement of our industrial partners (AREVA, EDF, ENDESA, INSTN-CEA, and Vattenfall) in the Programme. For the academic institutions, EMINE is the opportunity to provide a high level education aligned with the industrial needs. The international collaboration among universities helps improving the quality and the adoption of best practices. EMINE attracts good students to our centres whereas the EIT funding and the industrial involvement allows a number of activities that otherwise would have been difficult to carry out, such as the assistance of external industrial experts or field activities. MSc EMINE helps tomorrow's nuclear engineers take up the challenges the nuclear energy industry faces in terms of safety, social acceptability and waste management. By offering outstanding technical training and addressing the economic, social and political aspects of nuclear energy, the programme broadens the scope of traditional nuclear education.

1. Introduction

The European Master in Nuclear Energy, now running its 5th edition, is an international education initiative offered by KIC InnoEnergy under the framework of the European Institute of Innovation and Technology (EIT).

EMINE helps tomorrow's nuclear engineers take up the challenges that the nuclear energy industry faces in terms of safety, social acceptability and waste management. By offering outstanding technical training and addressing the economic, social and political issues of nuclear energy, this MSc programme broadens the scope of traditional nuclear education.

The uniqueness of EMINE lies in the strong involvement of its industrial partners. Four major players in nuclear energy – AREVA, EDF, ENDESA and Vattenfall – take active part in the programme. CEA, and its educational body, INSTN, actively contribute to teaching activities which allows EMINE to benefit from the expertise of one of the most important research centres in nuclear energy in Europe.

The master is fully taught in English and its duration is two years (120 ECTS credits). EMINE students acquire an in-depth knowledge of the nuclear industry, through a series of unique and specialised courses in the field of Nuclear Engineering, covering a wide range of subjects. In the first year students take courses at either of the following locations (see Figure 1):

- Royal Institute of Technology (KTH), Stockholm, Sweden
- Universitat Politècnica de Catalunya. BarcelonaTech (UPC), Barcelona, Spain

At the end of this first year, students from both UPC and KTH gather for a three week summer school at Grenoble École de Management. During the second year, students have the choice between 6 specialties offered by the following institutions:

- Grenoble Institute of Technology (Grenoble INP), France
- Paris-Saclay University (UPSay), France

Upon successful completion of the programme, students are awarded a double diploma from the first and second universities, as well as a certificate delivered by KIC Innonergy.

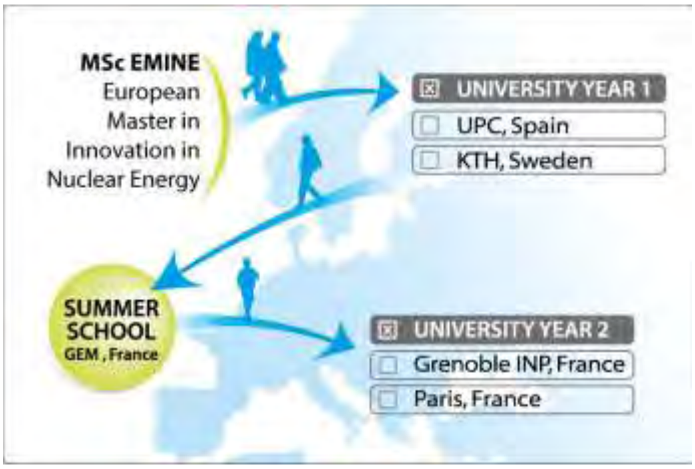

Figure 1. Mobility of students in MSc EMINE.

2. KIC InnoEnergy Master School

KIC InnoEnergy is an European company for innovation, business creation and education in sustainable energy. It is one of the so-called Knowledge and Innovation Communities created by the European Institute of Innovation and Technology (EIT)

The EIT was set up in March 2008 by the European Parliament and Council. Its mission is to:

- Contribute to the competitiveness of Europe, its sustainable economic growth and job creation by promoting and strengthening synergies and cooperation among businesses, education institutions and research organisations.
- Create favourable environments for creative thoughts, to enable world-class innovation and entrepreneurship to thrive in Europe.

The EIT strongly contributes to the objectives set out in Horizon 2020, in particular by addressing societal challenges in a manner that is complementary to other initiatives in these areas.

The EIT fully integrates the three sides of the Knowledge Triangle (higher education, research and business) by bringing together leading players from all these dimensions to cooperate within the KICs. The EIT's first three KICs were launched in 2010:

- Climate-KIC: addressing climate change mitigation and adaptation
- EIT Digital: addressing information and Communication Technologies
- KIC InnoEnergy: addressing sustainable energy

and a further two in 2014:

- EIT Health: addressing healthy living and active ageing
- EIT Raw Materials: addressing sustainable exploration, extraction, processing, recycling and substitution

KICs' activities cover the entire innovation chain, including training and education programmes, innovation projects and business incubators. Each KIC has been set up as a legal entity and has appointed a CEO to run its operations. KICs have a great degree of autonomy to define their legal status, internal organisation and working methods.

KIC InnoEnergy aims to achieve a sustainable energy future for Europe through innovation. Its mission is to build an operational framework between industry, research and higher education. The strategic objective is to become the leading engine of innovation in the field of sustainable energy.

KIC InnoEnergy is a world class alliance of top European players from Industry, Research, Universities and Business Schools (Figure 2). The Consortium consists of 27 shareholders and additional 160 associate and project partners. They are organised around six regional units, the so-called Co-Location Centres (CC): France, Benelux, Germany, Iberia, Poland Plus and Sweden.

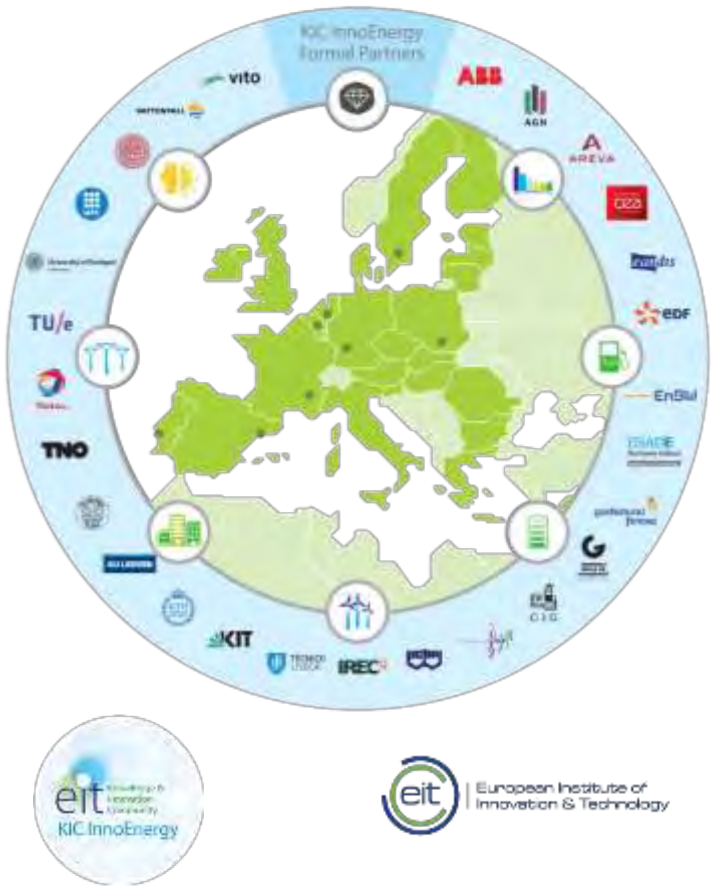

Figure 2. Kic Innoenergy as an European network.

KIC InnoEnergy Master School is running seven Master programmes in sustainable and low carbon energy that offer a combination of engineering and entrepreneurship. All these programmes deliver high quality content, covering a range of subjects considered crucial to meeting today's global energy challenges:

- MSc RENE – Renewable Energy
- MSc EMINE – European Master in Nuclear Energy
- MSc SENSE - Smart Electrical Networks and Systems
- MSc SELECT – Environomical Pathways to Sustainable Energy Systems
- MSc ENTECH – Energy Technologies
- MSc Energy for Smart Cities – Efficient Energy for Smart Cities
- MSc Clean Fossil and Alternative Fuels Energy

All these Programmes have international mobility as a common character:

- Students take courses in two different universities and countries.
- They get a training in innovation and entrepreneurship during the summer school
- Eventually students start an internship with one of KIC InnoEnergy partners.

Top European Universities are involved in the Master School:

AGH	AGH University of Science and Technology, Poland
INP	Grenoble Institute of Technology, France
IST	Instituto Superior Técnico, Portugal
KIT	Karlsruhe Institute of Technology, Germany
KUL	KU Leuven, Belgium
KTH	Royal Institute of Technology, Sweden
UPSay	Paris-Saclay University, France
SUT	Silesian University of Technology, Poland
TU/e	Eindhoven University of Technology, The Netherlands
UPC	Universitat Politècnica de Catalunya·BarcelonaTech, Spain
UU	Uppsala University, Sweden

and two business schools:

ESADE Business School, Spain
Grenoble École de Management, France

For all admitted students from the EU/EEA, and for the best among the students from other countries, KIC InnoEnergy covers the cost of the tuition fee. KIC InnoEnergy also offers scholarships to top applicants and also covers the costs related to events integrated in the curriculum (Kick-off event, summer school, field visits, European energy fairs…).

Some key figures of the Master School are given in Figure 3.

Figure 3. Some key figures of the KIC InnoEnergy Master School.

3. Description of the EMINE programme

The master provides an in-depth knowledge of the nuclear industry. The first year EMINE, either at KTH or at UPC, students acquire a series of competencies that are required in nuclear engineering: they learn the fundamentals of nuclear engineering, nuclear safety and radiation protection; they learn as well key aspects of the design and management of nuclear power plants.

During the summer school at GEM, students have the unique opportunity to develop transversal skills and acquire competences that are generally not delivered by standard master programmes and that will help them in their professional life: ranging from Energy Economics topics to facets of the Emotional Intelligence a leader must have, and including issues like Strategy and Innovation in the Energy sector and Intellectual Property.

During the second year students choose among the following majors, the first one carried out at Grenoble-INP and the other five at Paris-Saclay University (France):

- Materials Science for Nuclear Energy
- Nuclear Reactor Physics and Engineering
- Nuclear Plant Design
- Operations
- Fuel Cycle Engineering
- Decommissioning and Waste Management

The courses that students follow in the different itineraries are listed in tables 1 to 4. Towards the end of the second year, students develop a Master thesis during their internship at an industrial or research position. The involvement of EMINE industrial partners makes it easy for the students to find a Master thesis internship.

Table 1. Course structure for the EMINE first year at KTH.

Course	Credits (ECTS)	Type
Radiation, Protection, Dosimetry and Detectors	6	Mandatory
Sustainable Power Generation	9	Mandatory
Nuclear Reactor Physics, Major Course	9	Mandatory
Nuclear Reactor Technology Nuclear power Safety	8	Mandatory
Renewable Energy Technology	6	Elective
Thermal-Hydraulics in Nuclear Energy Engineering	6	Elective
Nuclear Physics	8	Elective
Radiation Damage in Materials	6	Elective
Generation IV Reactors	6	Elective
Nuclear Reactor Dynamics and Stability	6	Elective

Table 2. Course structure for the EMINE first year at UPC.

Course	Credits (ECTS)	Type
Fundamentals of nuclear engineering and radiation protection	8	Mandatory
Systems, components and materials	6	Mandatory
Reactor Physics and Thermal Hydraulics	7.5	Mandatory
Fuel Cycle and Environmental Impact (FCEI)	5.5	Mandatory
Course Project 1	3	Mandatory
Regulations and Safety	5	Mandatory
Management of nuclear power plants	8.5	Mandatory
Course Project 2	3	Mandatory
Fusion technology	4.5	Elective
Non-destructive testing methods	4.5	Elective
Core Design	4.5	Elective
Monte-Carlo methods for radiation transport calculation	4.5	Elective
Computational Fluid-Dynamics applied to Nuclear Technology	4.5	Elective

Table 3. Course structure for the major at Grenoble-INP (EMNE 2nd year).

Course (all mandatory)	Credits (ECTS)		Location
Reactor concept and materials	6		Grenoble INP
Material ageing in nuclear environment	6		Grenoble INP
Energy and Components EDF	6		
General approach to energy issues		1	Grenoble INP
Components		5	Materials Ageing Institute (EDF)
Nuclear Fuels CEA	6		CEA Cadarache
Innovation an management	6		GEM
Internship and Master Thesis	30		

Table 4. Course structure for the five majors at Paris-Saclay (EMINE 2nd year).

Nuclear Reactor Physics and Engineering	Credits (ETCS)
Safety Introduction	2
Functional description of a power station	3
Thermo hydraulics of reactors	6
Calculation Codes for Reactors	4
Nuclear Materials	5
Introductory Nuclear Physics	6
Neutronics – Part I	4
Labworks on PWR and Other Systems	4
Neutronics 2	4
Fuel and associated cycles; Criticality-Safety; Protection and Radiation Shielding	4
Internship	18

Nuclear plant design	Credits (ETCS)
Safety Introduction	2
Functional description of a power station	3
Risk Management	5
Environment & society	5
Radioprotection 1	2
Nuclear power station materials	5
Nuclear Thermal Hydraulics	5
Applied Nuclear Physics	5
Radioprotection 2	3
Design and construction of structures and infrastructures	4
Safety design: General Architecture, Systems and Equipment	4
Control Systems	4
Internship	18

Operations	Credits (ETCS)
Safety Introduction	2
Functional description of a power station	3
Risk Management	5
Environment & society	5
Radioprotection 1	2
Installation management	5
Nuclear Thermal Hydraulics	5
Applied Nuclear Physics	5
Radioprotection 2	3
Safety and production	4
Maintenance of nuclear installations	4
Instrumentation and calculation codes	4
Internship	18

Fuel Cycle Engineering	Credits (ETCS)
Safety Introduction	2
Functional description of a power station	3
Risk Management	5
Environment & society	5
Radioprotection 1	2
Nuclear fuel and the front end of the nuclear fuel cycle	5
Nuclear spent fuel recycling	5
Radioprotection 2	3
Waste conditioning	4
Radioactive waste management and repository design	4
Internship	18

Decommissioning and Waste Management	Credits (ETCS)
Safety Introduction	2
Functional description of a power station	3
Risk Management	5
Environment & society	5
Radioprotection 1	2
Politics, strategy and management of decommissioning	5
Sanitation and environment	5
Radioprotection 2	3
Practical training and simulation of the dismantling activities	4
Methods of decommissioning	4
Waste management and decommissioning of waste	4
Internship	18

The programme thus combines science and technology with management and innovation in the energy field and leadership skills in nuclear safety. Real industrial problems are presented in the classroom to be solved by students, and engaging pedagogical methods like PBL or e-learning strategies are used so as to create a learning atmosphere that help students achieve meaningful learning. The collaboration of the Industry is essential in achieving this goal.

4. Industrial involvement in EMINE

For the nuclear industry, it is a challenge to maintain the excellence and nuclear competence in our countries in particular and in Europe, in view of the recent changes towards nuclear phase out in some countries. The strong European exchange within EMINE is clearly beneficial and has been shown very fruitful already.

EMINE students benefit from the involvement of our industrial partners in the Programme. Industrial implication in the master takes a multifaceted form:

- A large number of topics and subjects are covered directly by lecturers from industrial partners or other collaborators from industry, research centres and Regulatory Authority, either at the universities' classrooms or at the premises of the companies (EDF, CEA-INSTN, Tecnatom). The “immersion” courses organized by CEA and EDF at their facilities offer the student a unique opportunity to discover the nuclear industry and their research activities.
- EMINE industrial partners participate in the Programme Steering Board and are active members of the EMINE consortium.
- Industrial partners and collaborators organise technical visits to their facilities: nuclear power plants, heavy components factories, laboratories, full-scope and incidental simulators, La Hague fuel reprocessing plant, Georges Besse II enrichment plant, Bure deep storage site, the Vattenfall Research Laboratory in Älvkarleby (Sweden), etc.
- The industrial partners offer internship positions for the students to develop their Master Thesis.

Some of the courses with a large implication of the industry are listed below:

- Leadership for Safety in the Nuclear Energy Industry (KTH, 6 ECTS). The course is organized around the presentation and analysis of actual cases (accidents and incidents, decision situations) from which relevant lessons are to be learnt. Lectures are given by expert guest lecturers from authorities and industry.
- Elements of the Back-end of the Nuclear Fuel Cycle: Geological Storage of Nuclear Spent Fuel (KTH, 7.5 ECTS). This course is organized within the EMINE programme by the KTH, the Center for University Studies Research and Development (Nova - Oskarshamn) and by the Swedish Nuclear Fuel and Waste Management Company (SKB) and supported by the Linnaeus University and the University of Illinois at Urbana-Champaign. The unique feature of the course is that the students visit Clab (an interim geological repository for spent fuel), the Laxemar Site (study area for bedrock and surface geology), the Äspö Hard Rock Laboratory (research laboratory for geological spent fuel disposal), and the Canister Laboratory (development centre for spent fuel encapsulation technology). See figure 4.
- Systems, components and Materials (UPC, 6 ECTS). More than one half of the lectures are delivered professionals from Tecnatom, CIEMAT, ENSA and Nuclenor.
- Fuel Cycle and Environmental Impact (UPC, 5.5 ECTS). About one half of the lectures are delivered professionals from ENUSA and AREVA.
- Regulations and Safety (UPC, 5 ECTS). Most of this course is lectured by external teachers (Regulatory Authority, ENUSA, CIEMAT, Tecnatom) or take place in an industrial facility (Tecnatom's Fulls Scope Simulator)
- Management of Nuclear Power Plants (UPC, 8.5 ECTS). Most of this course is lectured by external teachers (senior retired engineers from ANAV and Westinghouse, and active professionals from ANAV, Endesa, ENRESA, Tecnatom, and Westinghouse) or take place in an industrial facility (Tecnatom's Fulls Scope Simulator, Tecnatom's headquarters in Madrid, one Nuclear Power Plant, ENSA factory in Santander, Endesa headquarters in Madrid, etc.). See figure 4.

- Project course (UPC, 3 ECTS). This course is organised as a transversal PBL activity that students develop in teams and is followed up by specialists from industry together with academic staff.
- Energy and Components (Grenoble INP, 6 ECTS). These courses are delivered by EDF, the main part of it at its premises of the Materials Ageing Institute, where students spend 2 weeks (see figure 4). The courses consist of a detailed synopsis of selected operating experiences concerning PWR primary circuit components which EDF considers to be crucial issues for safety. Specific problems concerning fuel, fuel cladding, internals, pressure vessels, and water chemistry are detailed. This is a unique opportunity for students to learn what are the technological issues that engineers and researchers in materials have to tackle within nuclear industry.
- Nuclear Fuels (Grenoble INP, 6 ECTS). These courses are delivered by CEA – INSTN during 3 weeks stay at CEA Cadarache. This module gives a broad overview of the different key aspects of nuclear fuels which are useful to any engineer intending to work in the nuclear industry.
- Radioprotection 1 & 2 (Paris-Saclay, 5 ECTS in total). These courses are endorsed by CEA, EDF and IRSN
- Labworks on PWR and other systems (Paris-Saclay, 4 ECTS), endorsed by CEA.
- Fuel Cycles (Paris-Saclay, 4 ECTS). This module is endorsed by CEA for the Nuclear Reactor Physics and Engineering major.
- Design and construction of structures and infrastructures (Paris-Saclay, 4 ECTS), endorsed by EDF and BOUYGUES for the Nuclear Plant Design major.
- Systems and equipment (Paris-Saclay, 4 ECTS), endorsed by AREVA for the Nuclear Plant Design major.
- Operation management (Paris-Saclay, 5 ECTS), endorsed by CEA, AREVA and EDF for the Operations major.
- Safety and Production (Paris-Saclay, 4 ECTS), endorsed by EDF for the Operations major.
- Politics, strategy and management of decommissioning (Paris-Saclay, 5 ECTS), endorsed by EDF and CEA (39h, 5 ECTS) for the Decommissioning and Waste Management major.
- Methods of decommissioning (Paris-Saclay, 4 ECTS), endorsed by CEA, SALVAREM and EDF for the Decommissioning and Waste Management major.
- Separation and Recycling (Paris-Saclay, 6 ECTS), endorsed by CEA for the Fuel Cycle major.

Figure 4. Top-left: Visit to Äspö Hard Rock Laboratory. Top-right: In the turbine building of a PWR plant. Bottom-left: at the Materials Ageing Institute (EDF). Bottom-right: at the ENSA factory in Spain.

5. Sharping the saw

EMINE programme is in constant evolution as a result of the continuous interaction of the four local academic institutions with their respective industrial partners (some of them, as well, partners of EMINE). Moreover, the international collaboration among universities helps improving the quality and the adoption of best practices.

EMINE programme pedagogical evolution is also strongly supported by KIC InnoEnergy, which offers opportunities to support teacher's initiative for programme improvement.

In the last editions, new interesting courses have been developed at KTH combining efficiently theoretical and practical skills for the comprehensive competence building, like: Leadership for Safety in Nuclear Power Industry and Geological Storage of the Spent Nuclear Fuel, described above. Students graded those courses above 6.5 on a 0-7 scale. Moreover, the EMINE programme at KTH has developed and started to implement the integration of the entire programme into to E-learning platform in order to improve the pedagogy of the programme and to increase its efficiency.

At UPC, continuous adjustments are done on the contents of the courses. For instance, in the course on Systems, Components and Materials, a couple of relevant actions have been undertaken:

- The module on Systems (Tecnatom) has now a sharper focus on a limited number of systems; nevertheless, all the information given in previous years is made available to the students, so that they can use it in the assignments of the course on Management of Nuclear Power Plants.
- The module on Materials, mainly lectured by CIEMAT, has been made more attainable for students: whereas all the written information is still supplied to the students, lecturers pay more attention to the basic and crucial aspects.

An effort has been recently done at UPC to improve the exercises proposed for the course Management of Nuclear Power Plants. These exercises aimed to be as close as possible to actual engineering activities, e.g. analysing the suitability of the performance of any interface, designing a system, or specifying a component. Over the years these exercises have been adjusted to make them more effective learning tools, focusing the effort of the students on the more crucial aspects and increasing the instances of feedback provided by instructors.

At Grenoble INP a couple of initiatives have been developed as first raw tests. The first one is focused in the "learning by doing" principle and, more particularly, in the idea that "the best way to learn is to teach". A "student conference initiative on world energy issues", with real audience has been proposed and then organized and held with a strong implication of the students. Two different presentations have been made by two groups of 6 students each with the help of 3 scientific experts, in order to allow creativity and spontaneity both in the way of presenting facts and answering questions. Students had to use all their talent to make themselves as clear and convincing as possible. This initiative was a great success. The second initiative explores the innovation potential of the light "tangible games", which are typically games of cards and are the brand new trend of "gamification", in comparison to the "serious games", which impose heavy computing infrastructures.

At Paris-Saclay University the pedagogical committee, gathering the ten academic and industrial partners, improve annually the program during pedagogical meetings taking account for the students' evaluations. For example, the new EDF R&D and training campus in Plateau of Saclay will facilitate reactor simulator sessions for the students from 2017 on. Moreover, a set of conferences has been included in the program, to open perspectives and allow debate between experts and students on Energy themes. Some of them are given by AREVA and EDF senior experts.

EMINE programme has been recently evaluated by the students, who indicated a number of strengths and weaknesses and finally concluded:

- EMINE consolidates unique and specialised courses in the field of Nuclear Engineering – students are very happy about that.
- Providing double-diploma is still a unique thing in European Union. Ability to travel and learn is a dream of every student. While there are some hiccups on organisation side, most of the students are very pleased with this opportunity.
- Cooperation with industry enables EMINE to invite specialists to the lectures. Detailed insight is of high value in this field of science. Usually, these lecturers not only operate state of the art knowledge, but also give to the students an idea about possible work conditions and positions in future career.

6. Conclusions

MSc EMINE helps tomorrow's nuclear engineers take up the challenges the nuclear energy industry faces in terms of safety, social acceptability and waste management. By offering outstanding technical training and addressing the economic, social and political aspects of nuclear energy, the programme broadens the scope of traditional nuclear education.

KIC InnoEnergy offers scholarships to the best EMINE applicants and covers as well the participation costs at the hosting universities. This fact, along with the quality and focus of the programme and the industrial implication, helps EMINE attract good students.

The EIT funding and the industrial involvement allows a number of activities that otherwise would be difficult to carry out, such as the assistance of external industrial experts or field activities. The latter include several visits to factories, plants or even to an underground laboratory for Geological Storage of Spent Nuclear Fuel. The participation of external specialists in the lectures not only provides an insight on the state of the art, but also gives students an idea about possible work conditions and positions in their future career.

EMINE students receive the high-level technical education required to master the engineering complexities of nuclear power generation, as well as business training related to innovation issues and energy management. The programme helps students integrate the technical aspects of the nuclear industry with key political, economic and social issues.

EMINE offers students the possibility of carrying out an international MSc Programme of quality with large industrial involvement and allowing them to travel within Europe. The design of EMINE is attractive, combining science and technology with management and innovation in the energy field and leadership skills in nuclear safety, bringing to the classroom real industrial problems to be solved by students, and deploying a series of engaging pedagogical methods like PBL or e-learning strategies.

On finishing this MSc Programme, students enjoy of good job or PhD opportunities in the nuclear industry worldwide.

For more information

http://www.kic-innoenergy.com/education/master-school/msc-emine-european-master-in-nuclear-energy/

http://eit.europa.eu/

NEW METHODOLOGIES FOR IMPROVING NUCLEAR ENGINEERING SKILLS IN UPV

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ABSTRACT

New methodologies in teaching at university level are needed with the purpose that students acquire the competences and be prepared for the real labour market. In the field of nuclear engineering, the use of simulation tools has been stablished in some subjects to accomplish this goal.
The benefits of the introduction of computer codes in lab classes are enormous. Students analyse real transients occurred in nuclear power plants allowing in one hand the use of codes usually utilized by the nuclear industry and on the other hand a better understanding of the theoretical concepts. The practical classes have become a short trainee courses in each of the codes: PARCS, RELAP5, TRACE, MCNP, etc., and also in the different environment on which the codes are run: LINUX/UNIX and WINDOWS.
In this paper, we present the experiences of the use of nuclear codes for pedagogical purposes in different subjects of nuclear engineering focusing on the impact of this new methodology on the capabilities of the students.

1. Introduction

The teaching methodologies in higher education in Spain are changing gradually towards the implementation of the competence-based model following the guidelines of the ABET [1], EUR-ACE [2] and the Bologna process [3].

This model is based on the training and assessment in specific learning outcomes defined to achieve the correspondent competences. There are two types of competences: specific competences and generic competences. The first ones are the competences of a certain degree and the second ones refer to the competences that are common to all degrees. At Universitat Politècnica de València the specific competences are technical competences and there are 13 generic or transversal competences that refer to the soft skills like professional and ethical responsibility and leadership. Transversal competences are as important as the technical ones and can be the main key in getting a job.

Nuclear industry requires well-prepared graduate students not only with clear theoretical concepts but also with some practice experience. The calculations regarding nuclear safety requirements are carried out using computer codes, therefore, students should receive practical classes using some of these computer codes before they enter the job market.

In the nuclear engineering area of the chemical and nuclear engineering department at UPV, a group of professors have created a team for innovation and quality teaching (EICE - Equipo de Innovación Educativa) to accomplish these goals, in one hand the acquisition of technical and generic competences and on the other hand, the training in the use of nuclear computer codes. The EICE group is supported by the Institut de Ciències de l'Educació (ICE) at the Universitat Politècnica de València (UPV).

Within this team a new methodology is being introduced in some subjects based on the simulation-based training (SBT) [4] [5]. In this paper, we present the experiences in the application of this methodology in some subjects of nuclear technology, radiation protection and radiation technology.

The paper is organized as follows: next section is devoted to explain the main characteristics of the codes and its improvements to be used in class. Section 3 explains the experiences in radiation protection and radiation technology and section 4 explains the application in nuclear safety. Finally, the conclusions of the work are summarized in section 5.

2. Adaptation of the nuclear codes to educational purposes

Usually, neither models nor computer codes utilized in nuclear engineering to carry out simulation of the design basis accidents are not appropriate to be used in teaching as they are. They need some improvements in different aspects to be used in practical classes to reinforce the theoretical concepts.

In the Chemical and Nuclear Engineering Department, some codes have already been improved to become more user-friendly to be able to be used in teaching nuclear safety and radiation protection related subjects. The selected codes are the ones that are commonly used by the nuclear community in real practice. These codes are: TRAC-BF1 [6], TRACE [7], RELAP5 [8], COBRA-TF [9], PARCS [10] and MCNP [11]. TRAC-BF1, TRACE, RELAP5 and COBRA-TF are thermalhydraulic codes; they solve the equations governing the mass continuity, and momentum and energy conservation. PARCS is a 3D neutronic code that solves the approximation of the neutron diffusion equation in two groups of energy. The thermalhydraulic code is coupled to the neutronic code to capture all possible effects of the event under study. This is another aspect that students find out for the first time in this new applied methodology. The coupling usually is a sequential coupling in which each code solves their equations separately at each time step and share only the information that they need from the other at the time it is required.

Computer-Aided Design and Computer Aided Engineering tools are used by engineers, designers, and analysts in many ways depending on the profession of the user and the type of software in question. The nuclear engineering community has invested heavily in coupling finite element analysis methods with these tools. Often, along with these products, advanced visualization of results capabilities exist.

The improvements made in the nuclear codes to be used as pedagogical tools are the following:

- Automatic generation of the input files
- Automatic management of the output data files with plots and 3D visualization of the results.

These tasks have been a part of the work presented by many students in different final degree projects and final master thesis in order to get the corresponding diploma.

The improvement has changed drastically the way of working with these codes, not only for teaching purposes, but also for its use in researching activities.

The input file is usually an ASCII file that contains a lot of information about the geometry, thermal variables, control variables, etc. To obtain the input file for these codes easier and faster, a program has been implemented using Fortran and Matlab languages. Just running the program, the input file is automatically obtained with the need of modifying only some perfectly known parameters. The main advantage of this program to be used in class is the speed with which the input file is obtained allowing dedicating the class to understand the main cards and the adjustment process of the steady state case.

For example, the program to automatically obtain the input files for PARCS code is called *Gen_inp* and it has to be fed with three files that come from the real plant data. The program is executed in fractions of a second to obtain 4 input files for PARCS. The program that reads the output file is called *Gen_output* and plots the main variables of the event, usually, the reactor power, the evolution of reactivities, the enthalpy, etc.

Another capability added to PARCS and COBRA-TF is the possibility of drawing three-dimensional plots. The source code of PARCS and COBRA-TF has been modified to write the values of the most important variables in a *.vtk* (*Visualization Toolkit*) format file that is read by programs like ParaView [12] and VisIt [13]. This allows analyzing the main output variables in a very fast way, facilitating the use of these codes in a class and giving a visualization of the results in 3D.

MCNP Version 6.0 (MCNP6) [14] has a new capability that permits tracking of neutrons, electrons and photons on an unstructured mesh which is embedded as a mesh universe within its legacy geometry capability. These new tools are not only attractive to and of primary importance to Monte Carlo beginners who need to construct geometries for their work.

The mesh geometry is created through Abaqus/CAE software [15] using its solid modeling capabilities. Transport results are calculated for mesh elements through a path length estimator while element to element tracking is performed on the mesh. The results from MCNP can be exported to Abaqus/CAE for visualization or other-physics analysis.

The degree of fidelity between the CAE representation and the unstructured mesh is generally good and depends to a degree upon the user's willingness, ability, and need to refine the model.

3. Experiences in the application of the simulation-based training

In this section, the methodology used in different subjects to include the simulation and the results obtained are presented.

3.1 SBT in Radiation technology and radiation protection

Nowadays it is important to include the teaching of Monte Carlo codes in the curriculum of undergraduate and postgraduate students of schools of Nuclear Engineering. This is due to the intensive use of Monte Carlo codes in radiation protection and other engineering fields such as medical physics or radiation detectors design and analysis.

MCNP is a widely used Monte Carlo code describing the transport of particles through matter, which is developed, maintained, and upgraded through Los Alamos National Laboratory, LANL [16].

The teaching of Monte Carlo is usually delegated to research centers, usually when students began to work on their Masters theses. At the UPV, over the last years, teaching staff of the Nuclear Engineering Department have been experimenting with extending the reach of Monte Carlo simulation into the undergraduate/postgraduate curriculum to: enhance the professional capabilities of students and remedy gaps in the curriculum.

Moreover, each year, several students work on their thesis project using MCNP as the simulation tool in their research. That is why in UPV, the need to design and set in place a course to teach MCNP efficiently to undergraduate and postgraduate students became of primary importance.

The course consists of practical computing sessions interlaced with theoretical seminars. The students work in a computer science laboratory and they are supported in their learning process by different professors and/or lecturers.

The primary barrier, at postgraduate and undergraduate levels was the lack of familiarity with programming language and we found that students had no awareness of Monte Carlo methods, or of the use of the Linux platform. That is why initial classes had to include these concepts.

Since radiation shielding is of primary importance in planning the safety conditions of exposed personnel in radioactive facilities, the MCNP students deal with the application of radiation transport calculations using the Monte Carlo method, in particular, the MCNP code, in calculations of radiation protection situations as well as radiation detection instrument responses.

The objective of this computer sessions is to provide training and guidance for applying MCNP in numerical dosimetry and promote the exchange of knowledge between experienced professors in these fields to students. To that, we have established the central problem – developing a MCNP-based dosimetric system for radiotherapy; and several sub-problems that might build toward this main problem have to be solved.

In Monte Carlo laboratory classes students work individually and at the end of the course they must deliver a portfolio with the inputs and output of the analyzed problems. These are the evidences that professors have to check if learning outcomes have been reached. Some of the images that students included in their portfolios are shown in Figure 1:

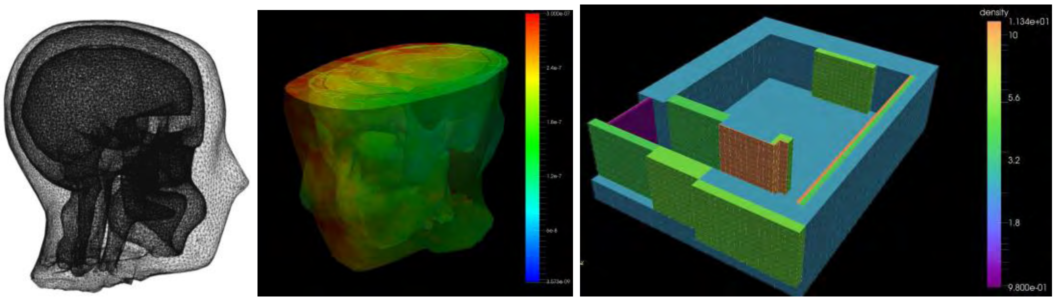

Fig 1. Images extracted from students portfolios.

3.2 SBT in Nuclear Technology

The contents of the subject nuclear technology are often explained in master classes. The concepts are related to mathematical expressions, advanced numerical methods, nuclear reactor physics, etc. To introduce the thermalhydraulic and neutronic calculations, the examples solved in class consists of simplified models. The use of computer codes helps to enhance the effectiveness of classes about nuclear energy concepts allowing the analysis of more complex systems.

A new teaching methodology has been carried out in nuclear safety engineering courses in UPV that consists of the following steps:

- Participative master class. Teacher introduces new concepts and solves examples encouraging the participation of students.
- Introductory practical classes in which the main features of the codes are explained. In this classes, students run simple examples with the codes without coupling.
- Practical classes: students use simulation to analyze an event that can occur in a real nuclear power plant.

The assignment for students is a portfolio in which they have to explain all the calculations, data in input files and analysis of the results of the corresponding event that they were asked to run. Students have to include in this portfolio their reflections on the subject, indicating what they have learnt in each session of the course [17].

In Figure 2 some of the 3D plots obtained from PARCS using Paraview postprocessor are shown [18].

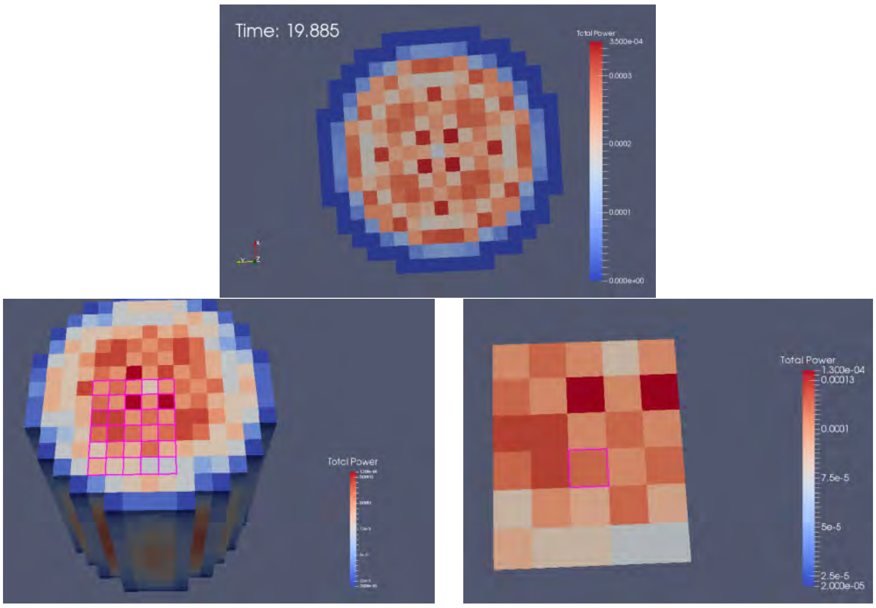

Fig 2. 3D plots of the power distribution in the reactor core.

3D plots obtained from COBRA-TF using Paraview postprocessor are shown in Figure 3 [18].

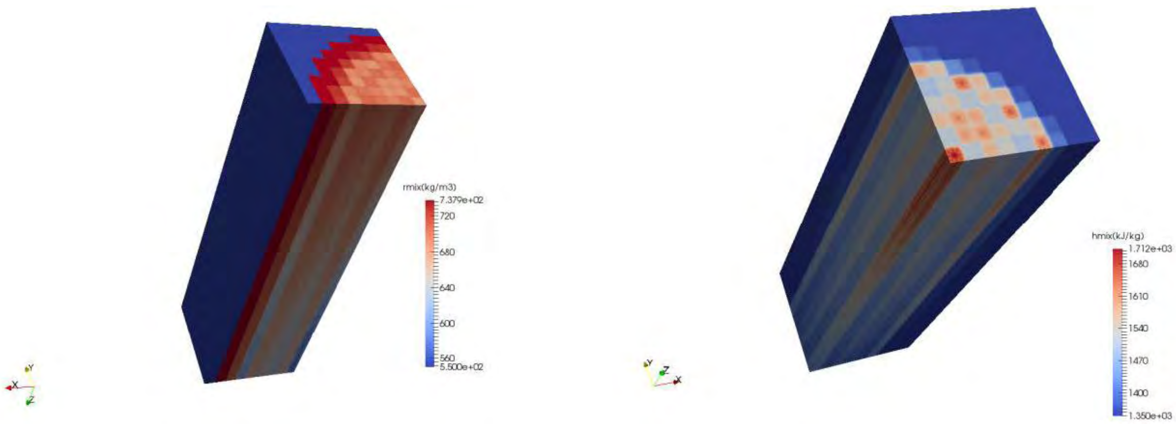

Fig 3. 3D plots of the density and enthalpy distributions in the reactor core.

4. Conclusions

A new methodology has been implemented in the courses at UPV related to nuclear safety and nuclear engineering. The experience has been great for students that are able to use codes used by nuclear industry with new user-friendly capabilities.

The continuously increasing number of scientists and institutions using Monte Carlo codes in radiation protection and in medical applications requires this matter to be included in student curriculums, to prepare future professionals. Therefore, we have been working on developing a set of MCNP laboratory classes for under and postgraduate students of the Nuclear Engineering department of the UPV using the computer-aided design and computer aided engineering tools that have been coupled recently with Monte Carlo methods. The defined classes are mainly suited for the Medical Applications domain but it may be arranged also to other fields of research, to enhance learning in reactor physics.

On the other hand, using thermalhydraulic and neutron kinetics codes in nuclear safety analysis related courses make that at the end of the course, students have acquired new skills in:

- Computer science
- Coupling codes
- Main thermalhydraulic code features
- Main neutronic code features
- Analysis of an event: from the definition of the models to the analysis of the results.

Simulation has also increased the motivation of students towards the nuclear subjects. In viewing the applications directly in class, they can realize that there are many chances in nuclear industry for them to work after obtaining the diploma.

5. Acknowledgments

Authors would like to express their gratitude to the professor’s team of the EICE (Equipo de Innovación Educativa) called SEERI Simulación en la Enseñanza de Radiaciones Ionizantes for their effort in carrying out this work. The EICE group is supported by the Institut de Ciències de l’Educació (ICE) at the Universitat Politècnica de València (UPV).

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MASTER IN RADIATION PROTECTION FOR RADIOACTIVE AND NUCLEAR INSTALLATIONS

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ABSTRACT

In this work the “Master in Radiation Protection for Radioactive and Nuclear Facilities” is presented. This course, which is mostly e-learning based, is managed by the Polytechnic University of Valencia (Spain) and coordinated by Titania Servicios Tecnológicos, S.L., a spin-off of this university. It is a 65-credit course that lasts a full academic year. The fifth edition started on 5th October 2015 and will end on July 15th, 2016. The master is divided into 4 modules, one general, two specific and one advanced. In the “General Module” there is a radiation protection overview of basic concepts on radiation physics, detection and measurements, radiation dosimetry, etc. The two specific modules are called “Module on Radioactive Facilities”, and “Module on Nuclear Facilities”. The first one is divided into Industrial Facilities, Nuclear Medicine, Radiotherapy, Radio-diagnosis, and Research Installations. The second specific module is based on Safety and Radiation Shielding, Processing, Storage and Disposal of Nuclear Wastes, Decommissioning and Environmental Management. For each type of facility, attention is given to its general characteristics, operational radiation protection and safety, and specific legislation. In the “Advanced Module” students learn about advanced concepts of radiation protection as Internal Dosimetry, Environmental Radioactivity, Radioactive and Nuclear Emergencies, Atmospheric Dispersion, ALARA at Nuclear Facilities, Monte Carlo method, etc. After each module, there is some practical exercises to be developed in the related installations. The aim of the Master is to progress in the development of competences in the radioactive and nuclear areas of knowledge with a special focus on radiation protection (nuclear safety culture and radioactive waste management; radiation protection in radioactive facilities: industrial, medical and research). In the long term, it will contribute to improve the safety and radiation protection culture and hence, the safety of nuclear and radioactive installations.

1. Introduction

The aim of this work is to present the “Master in Radiation Protection for Radioactive and Nuclear Facilities”. This is a postgraduate training in Radiological protection managed by Universitat Politècnica de València (UPV), applied to nuclear and radioactive facilities. It is based on e-learning methodology and designed to cover various contents and applications in different areas and sections, related to Radiological protection general concepts, specific skills for radioactive facilities and nuclear facilities. The master includes laboratory exercises related with different items studied during the training. At the end of the master, there are some sessions held at UPV for final revision of matters and an examination.

This master has been addressed for people interested in radiation protection (nuclear safety culture and radioactive waste management, radiation protection in radioactive facilities: industrial, medical and research). It is required, at least, a university degree to access to the master. It qualifies students to carry out tasks related to that of a Radiological Protection Expert (RPE) and Radiological Protection Officer (RPO), working in Radiological Protection Services. In addition, it could be interesting for specialists working at Occupational Health and Safety Services.

The master is managed by the Chemical and Nuclear Engineering Department, of the UPV while it is coordinated by Titania Servicios Tecnológicos (Titania), which is a UPV spin-off. Several entities, such as hospitals, research centers, industrial facilities, and nuclear power plants, collaborate in the master as they have a wide experience in Radiological Protection and in the nuclear field,. Some examples are Iberdrola and Enresa (the Spanish company in charge of radioactive waste management). A special mention requires the collaboration of the Spanish Nuclear Safety Council (CSN), which coordinates the Nuclear and Radioactive Emergency area. All these entities collaborate giving theoretical and practical lessons in the master modules and allowing the use of their installations, such as hospitals or research centers, for developing practical exercises.

2. Material and Methods

The Master in Radiological Protection for Radioactive and Nuclear Installations has a duration of 65 ECTS. It lasts for a whole academic year and it is divided into four modules, one general, two specific and one advanced.

The general module covers the basic concepts of Radiological Protection. One of the specific modules is devoted to “Radioactive Installations”, which is divided into Industrial Facilities, Nuclear Medicine, Radiotherapy, Radiodiagnostic, and Research Installations. The other specific module, “Nuclear Installations and Fuel Cycle”, refers to Safety and Radiation Shielding, Processing, Storage and Disposal of Nuclear Wastes, Decommissioning and Environmental Management. For each type of installation, attention is given to their general characteristics, operational Radiological Protection, and specific legislation. The “Nuclear Installations and the Fuel Cycle” module also includes a Nuclear Safety topic. The last module, the Advanced Module, is focused on advanced concepts of radiation and Radiological Protection.

The course is mostly e-learning based. It is implemented on the *PoliformaT* platform of the UPV, by presentations, explanatory practical videos, interactive tasks, self-assessments, to facilitate self-learning by students. Advanced technological methods have been employed, so they allow to adapt the training with flexibility to the experience provided by the expert professionals and make a follow-up of the students.

Once the students have access to the platform, there is a main menu shown in Figure 1. The environment of the *PoliformaT* platform is friendly and intuitive, which makes it easy to use. It has various tools with different functions depending on whether one is an administrator (for instance a course professor o lecturer), with a wider management capacity, or whether one is a student, in which case permission is restricted to those authorized by administrators. For this reason, the existence of control tools is important as they guarantee efficient follow-up and control by the entity providing the course.

Figure 1: *PoliformaT* main screen of the Master Module.

There are many interesting tools and resources in *PoliformaT* platform for students to follow the contents of the master. They can see the course timetable and important dates such as those of examinations. Students can view the latest news about the progress of the course. In the Program option, they can download the list of materials that will be followed during the course. There is a specific tool for Contents, with the main material available to the student by areas with the presentations, explanatory videos, interactive tasks, etc. that cover the major objectives of the course.

Students can view complementary material as extra information for those who want to go deeper into a subject. Self-assessments for each learning block permit to check whether the progress of students to learn contents achieves the main objective.

On other hand, to facilitate the training of the students several on-line sessions are planned. They include remote reviews and the resolution of doubts of each area using specific software (named *Policonecta*) to be able to contact the students wherever they are. The student will only need a computer connected to Internet, a webcam, headphones and a microphone. Moreover, in these sessions the students can make an examination to control their progress. The access to these sessions may be performed online too. Figure 2 shows an example of one of these sessions.

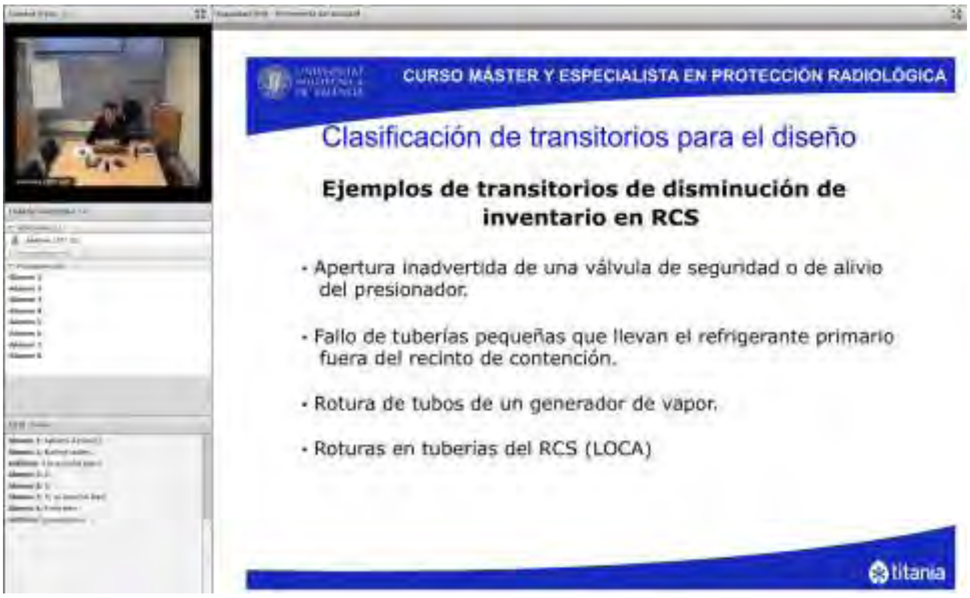

Figure 2: *Policonecta* session.

Finally, at the end of each module the students must complete their training by attending a classroom seminar, to help them as a final revision of the module and to solve any queries related with the module contents. There are also some practical sessions as visits to specific industrial facilities, laboratories, research centers and nuclear installations and a classroom examination to check the knowledge of students.

These practical sessions take place at UPV and at the dependencies of the entities that collaborate to the master. As an example in Figure 3 there is a picture of the José Cabrera Nuclear Power Plant, which is being dismantled.

Figure 3: Practical session in the José Cabrera Power Plant, which is being dismantled.

Some statistics tools can be used by the administrator to quickly follow up the steps that each student takes on the platform. He has at his disposal many automatic reports. Figure 4 shows an example. The administrator can see the visits that have been made by different students over a period of time as well as the resources and contents accessed by students during the visits.

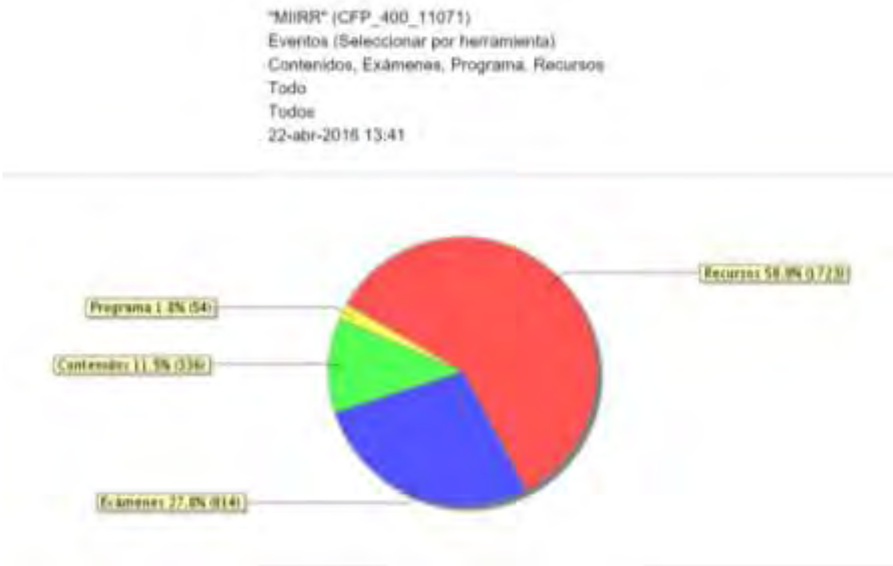

Figure 4: Screen in which can be appreciated a visit and event report.

3. Results and Discussion

The Master in Radiation Protection for Radioactive and Nuclear Facilities has been consolidated through its five editions as a powerful training in the field of Radiation Protection. Some highlights could be remarked in this sense:

- In the first editions of the master, it has been achieved a high level in the satisfaction of students, as showed by the surveys carried out at the end of the course.

- The growing of the number of interested people has been increased during these years. The master webpage registered 21,500 visitors since the beginning of the first edition and 700 people interested have contacted with the master Direction/Coordination asking for more information.

- Several professional experts from the collaborating institutions participate in the master so its connection with practical approach is essential. One of the most important collaborators to the master is the CSN, as Regulator in Spain of Radiological Protection and Nuclear Safety. They coordinate the area of nuclear and radiological emergencies in the advanced module.

- The yearly average number of students is 20 coming from different countries. In the last edition (2014/2015) participated students from different localizations as it is shown in the Figure 5.

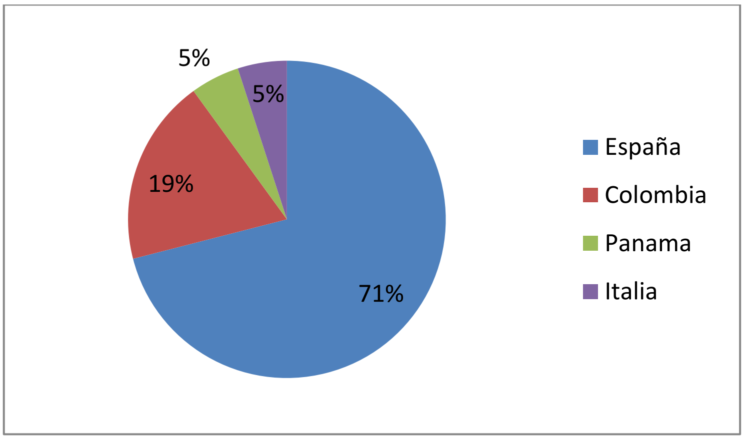

Fig 5: Origin of students for the 2014/2015 edition.

- The fifth edition (2015/16) of the Master includes a new area about internal dosimetry in the advanced module with new practical sessions.

4. Conclusions

The experience during these editions of the Master in Radiation Protection for Radioactive and Nuclear Facilities shows the importance of this type of professional training using e-learning tools. A flexible and balanced training system can be achieved, which is more personalized for each individual.

The implementation of the Master provides training in Radiological Protection and Nuclear Safety mostly e-learning based, covering general and specific topics of nuclear power plants, radioactive installations, as well as industrial, research and medical facilities.

The development and designing of this type of training makes it highly interesting. To have a robust tool for following up and controlling the course effectively increases this interest. The Master is addressed to people interested in extending their knowledge in Radiological Protection and Nuclear Safety for radioactive and nuclear facilities, to develop a higher level of tasks in these fields.

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RECENT EXPERIMENTS IN NUCLEAR ENGINEERING EDUCATION IN ITALY

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ABSTRACT

Education has a crucial role for the future of nuclear energy, even more after the Fukushima accident. It is necessary to guarantee the natural turn-over of human resources employed in the field and to prepare qualified engineers and researchers to study and design the future generation of nuclear systems, with a stress on enhanced safety, more efficient fuel cycle, radioactive waste transmutation, security. The Italian situation is peculiar owing to the nuclear energy phase-out, that was decided, after a referendum in 1987, following the Chernobyl accident, and more recently, after another referendum in June 2011, just after the Fukushima- Daiichi accident. After a short history of the Nuclear Engineering education in Italy since 1955 the paper presents the current Nuclear Engineering courses in Italy, and in particular the Master level Nuclear Engineering Course that has been organised this year in collaboration between the Politecnico di Milano and Politecnico di Torino.

1. Introduction

The present panorama of nuclear energy in the world is quite varied: in “old industrial Countries”, a recent wave of renaissance was somehow slowed down by the Fukushima Daiichi accident [1]; there are problems with public acceptance due to poor awareness of risks and benefits, lack of accurate information, no real incentive. There is also some uncertainty in taking decisions at the political level owing to the lack of belief in policy makers and the fear of loosing consensus; the issue of the increasing cost to build the plant is also important, although the costs depends strongly on the Countries [2]. Instead in “new industrial Countries” the access to nuclear energy is regarded as an opportunity and is being largely exploited: new constructions are carried on. In such contest education is fundamental for the future of nuclear energy, even more after the Fukushima accident, as it is necessary for the natural turn-over of human resources and to prepare qualified engineers and researchers to study and design the future generation of nuclear systems, which have to be characterized by enhanced safety and security, sustainability and more efficient fuel cycle, radioactive waste transmutation. The need to preserve, enhance or strengthen nuclear knowledge, skill and aptitude (ECVET) is recognized by the main international Institutions, like IAEA: there are indicators, e.g. declining university enrolment and high retirement expectations, that future expertise is at risk. The Italian situation is peculiar but it must be mentioned that when the Italian government decided to abandon the nuclear energy production, at the end of eighties, gave in some way the universities and research Centres, like ENEA, the task to maintain alive the expertise, the research and the education in this area, also to address the issues of nuclear fusion, of decommissioning of the nuclear facilities and of radioactive waste management. After a quick history of the Nuclear Engineering education in Italy since 1955, the paper presents the current Nuclear engineering courses in Italy and, in particular, the Master level Nuclear Engineering Course that has been organised this year in collaboration between the Politecnico di Milano and Politecnico di Torino is presented.

2. Nuclear engineering education

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 Italy the problem has become really dramatic, because the Country has pulled out of the nuclear generation of electricity and resources were reduced 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. Similar concern for nuclear education has been also stated by the European Nuclear Society in very recent times [3]. Particularly significant is a statement by OECD Steering Committee [4] for Nuclear Energy / European Nuclear Society: “the availability of qualified human resources is a prerequisite to the safe operation of existing nuclear power plants as well as to the recourse to nuclear energy in general: a regular monitoring of the availability and requirements of qualified human resources is necessary to match the existing and future needs; 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”. Hence the OECD Steering Committee for Nuclear Energy conveyed 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”. 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”. In September 2002, the (IAEA) General Conference requested the Director General to note the high level of interest of Member States in the range of issues associated with preserving and enhancing nuclear knowledge in the process of preparing the Agency's program. Worry for nuclear education is shared by several international institutions (OECD, ANS, NEA, IAEA, EU…), industries, utilities and research labs (CEA, AREVA, DOE, NRC…). After the Fukushima- Daiichi accident the risk to have insufficient human resources in the next years is even more realistic than in the past, when a growing interest for nuclear educational programs was experimented in many Countries. It must be acknowledged that to produce an engineer (Master graduate) for industry and utilities more than 5 years are needed; to produce a PhD graduate more than 8 years are needed; to prepare a good university instructor more than 10 years are needed and good motivations and perspectives must be offered to the best youth. The profile of the Nuclear engineer is implied by the courses he is supposed to attend and pass at the MSc level and by the related learning outcomes. In the past, there was some need to clarify that Nuclear engineers cannot be identified just with physicists or experts in neutronics or in any other single matter related to nuclear, but Nuclear engineers should be identified with engineers having that broad spectrum of competences needed to design, construct and operate safe nuclear power plants.

3. Nuclear engineering education in Italy

3.1 Short history

Italy started to build nuclear power plants early: three first generation nuclear power plants (PWR, BWR, Magnox) started operation before middle sixties. The 860 MW_e Caorso BWR NPP started running in 1981: a 2000 MW_e NPP with two BWRs was under construction in Montalto di Castro in the eighties; a 2000 MW_e NPP with two PWRs was planned in Piedmont and several research reactors were built in the same period. As regards the education, since 1955 several initiatives (in the form of post degree Courses for mechanical, electrical, chemical engineers) were undertaken in Italy in the field of the nuclear education: from 1960 to 1966 six Universities set up Nuclear engineering Courses that delivered a five year N.E. degree: “Polytechnic Schools” of Milano and Torino, universities of Bologna, Pisa, Palermo and Roma. The number of Nuclear engineering enrolled students increased up steadily until the first nineties, and after then, with some oscillations, decreased to the values of less than ten per year in each of the mentioned universities. The number of the Nuclear engineering graduated students per year increased in Italy up to about 250 in the first eighties and decreased later to less than 100 (Fig.1).

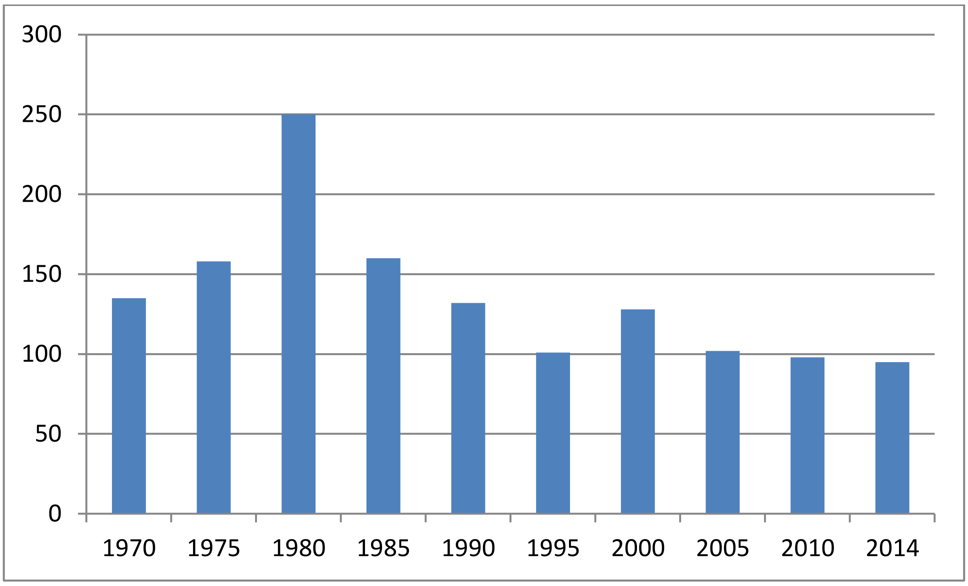

Fig. 1 History of Nuclear engineering graduated students in Italy

After the first Referendum in 1987 either the Italian universities and the research centers or the industry and the national utility began to struggle for maintaining the nuclear knowledge, in order to be able to manage the radiation protection and decommissioning issues and to be competitive in the European nuclear market. The Board of each N.E. Course decided:

- to stress the methodology aspects and the contents that could be easily extended to whatever engineering application, like the thermal-mechanics, thermal- hydraulics, reliability and risk analysis
- to strength the topics concerning the innovative reactors and the nuclear fusion engineering, as well as the issues related to the radiation protection
- to intensify strongly the contacts with universities and Research Centres abroad.

Some years later, at beginning of the XXI century, a significant effort has been carried out in Europe to homogenize the various academic systems for all disciplines: 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, together with the European Credit Transfer System (ECTS), which in Italy means 10 hours of lecture (and about 25 hours of student global commitment) per ECTS. It is worth mentioning that the nuclear education has profited from this framework, enhancing mobility of students for courses, stages and Master thesis. In 2012 the Italian Government has issued a document on the “National Energy strategic plan: for a more competitive and sustainable energy”, reporting that “as regards the Nuclear energy the prevision for the next 10 years in the world is an increase in Asian Countries (in particular China, Korea, India, Russia), while in the West and particularly in Europe no significant increase of the Nuclear Power Plants will occur because of the high construction costs and the safety issues of this technology. In USA and Europe (and particularly in Italy) the emphasis will be put on the NPPs decommissioning and wastes treatment and storage. Further research work is needed to improve the NPPs safety and security. Concerning the Italian situation in the long term, it is important to increase the international collaborations on the nuclear safety, on the IV generation reactors and on the nuclear fusion”.

3.2 Present situation

The Nuclear engineering courses in Italy have always tried to give the students rather good bases and a system oriented approach to problems that can be used successfully in different engineering areas; so the Italian nuclear engineers are rather able to deal with complex problems and often are appreciated abroad, but, as pointed out above, in Europe, but especially in Italy, universities have gone through several years of difficult time as far as financial and human resources are concerned. Retirement of several professors are practically empting many nuclear research teams in some Italian universities, making hard to maintain nuclear engineering programs. 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, in order 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 [5]) has allowed them to perform well both scientific research and education. At the European level a large scale consortium of universities (ENEN [6]), that includes CIRTEN, has been set up for establishing common requirements for a mutual recognition of degrees. The recognition of education requisites will certainly favor the mobility of students within European universities (often by means of Erasmus programme) and the recognition of degrees can enhance mobility of graduates for PhD and for job placements in industry and research laboratories. Besides enhanced collaborations with many European universities, several agreement have been established with many universities in Asia and America. Within this framework, several student and young researcher exchanges have taken place among the involved institutions and 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 good 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, nuclear) around the world, in industry, labs and academia. The Nuclear engineering education in Italy is currently offered at Master and PhD levels in Milano, Torino, Pisa and Palermo universities, and to a lesser extent also in Roma and Bologna Universities. The Master degree names are different: Nuclear engineering in Milano and Pisa, Energy and Nuclear engineering in Torino and Palermo, Energy engineering in Roma and Bologna, but the content of the basic nuclear modules is similar. There are several topics that are common to most universities: Reactor engineering and technology, Reactor physics, Nuclear power plant thermal hydraulics, Safety and reliability of nuclear facilities, Reactor engineering materials, Radiology and radiation protection, Nuclear fuel cycle and applied radiochemistry, NPP decommissioning and waste management. Other topics like Nuclear Fusion, Nuclear medicine applications, Nuclear instrumentation and measurements, Plasma industrial applications are addressed in some Universities. As an example at Politecnico di Torino the enrolled students in Energy and Nuclear engineering can choose the Technology and Nuclear applications branch with 72 nuclear credits plus 16 credit nuclear subject thesis. In Table 1 the nuclear engineering ECTS in each university is presented. There are also some Nuclear engineering courses at bachelor level in some universities. E-learning methods, as well as the use of social networks to communicate with the students, are widely adopted: an example is the Facebook page of the Pisa university:
http://www.facebook.com/pages/Studiare-Ingegneria-Nucleare-a-Pisa-Nuclear-Engineering-Studies-in-Pisa/391575160888508#!/pages/Studiare-Ingegneria-Nucleare-a-Pisa-Nuclear-Engineering-Studies-in-Pisa/391575160888508.

Program name	University	Nuclear engineering ECTS
Nuclear engineering	Politecnico di Milano	85
Nuclear engineering	Università di Pisa	90
Energy and Nuclear engineering	Politecnico di Torino	72
Energy and Nuclear engineering	Università di Palermo	66
Energy engineering	Università di Roma	45
Energy engineering	Università di Bologna	36

Tab 1: Master degree Nuclear engineering credits in Italian universities

In the last years the interest of young people for energy problems has increased dramatically. As an example Fig.2 shows the evolution of the enrolled students at Politecnico di Torino in ten years. In the last years about 20% of these students has chosen the Nuclear engineering branch, but for all students some Nuclear engineering courses are mandatory.

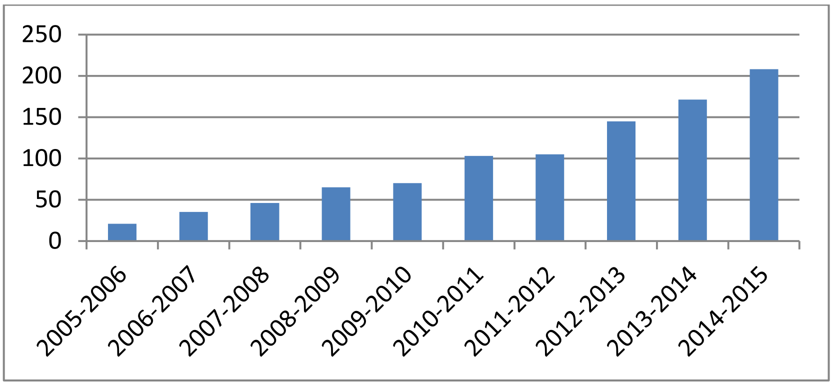

Fig. 2. Students enrollment number evolution in Energy and Nuclear engineering Master at Politecnico di Torino

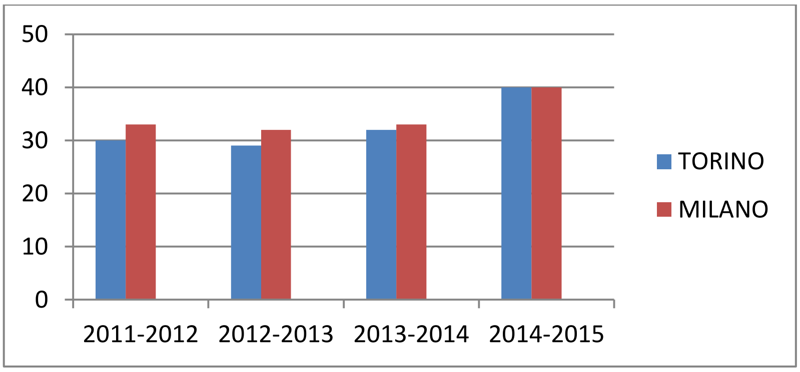

Fig. 3. Students enrollment number in Nuclear engineering Master at Politecnico di Torino and Politecnico di Milano in the last four years

The number of Master students in Nuclear engineering in Italian universities has been about constant, also after the Fukushima Daiichi accident. For instance Fig.3 shows the enrolled students evolution in the last five years at Milano and Torino Polytechnic Schools. The number of Master graduates in Nuclear engineering in Italian universities amounts in the last years to about 100 per year. Concerning the teachers, at present 64 Professors and Assistant Professors in the six Italian universities educate the students in the Nuclear engineering field (Fig. 4), carrying out researches on nuclear engineering related issues; this number is decreased in the last years due to the professors retirements and the economic difficulties (Fig. 5).

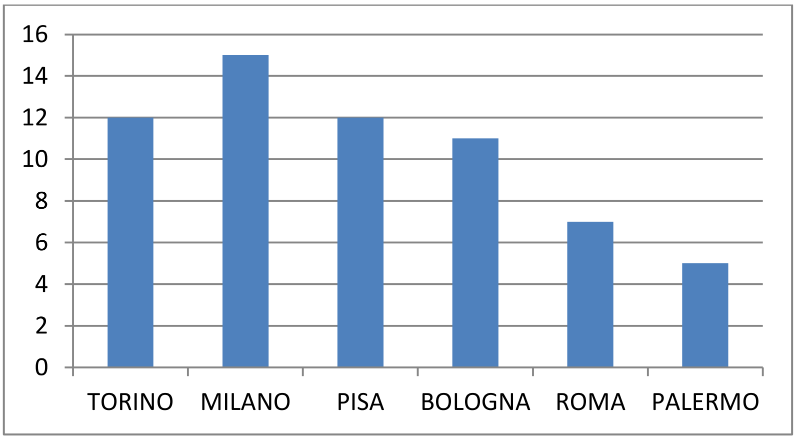

Fig. 4. Current Nuclear engineering teachers in each university

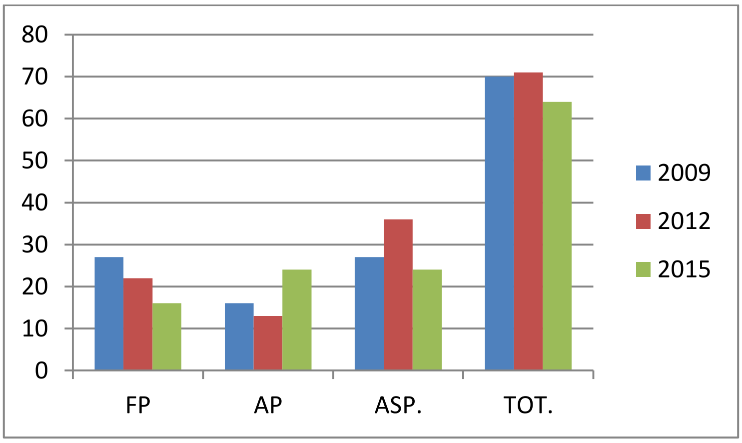

Fig.5. Nuclear engineering teachers evolution in Italy (FP full prof., AP associate prof., ASP. assistant prof.)

4. International collaborations

Concerning the international collaborations in the education field, some actions have been taken by the Italian universities: by activating, often as CIRTEN, several international collaborations and undertakings like ENEN (European Nuclear Engineering Network); by participating, as CIRTEN, to several Nuclear engineering education European projects (FP6 and FP7): ENEN I, II, III, Neptuno, ENEN-RU, ENEN-China, TRASNUSAFE, GENTLE, NUSHARE, ANNETTE. There is an enhanced mobility of Italian students in Europe, stimulated by the adoption of the Bologna system and by the ENEN initiatives like the European Master of Science in Nuclear Engineering (EMSNE). EMSNE has been implemented since 2006, on the basis of common reference curricula and at least 20 nuclear ECTS gained abroad: it promotes and facilitates mobility of students and teachers and allows the definition and assessment of ENEN international exchange courses. “EMSNE Certificate” is recognised among ENEN Members (more than 45 universities) with the objectives 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 possibility to adhere to similar curricula in Europe would facilitate student exchanges with a great benefit for students, that learn to be “international”. It further develops the collaboration in nuclear education and training of students, researchers and professionals all over Europe, ensures the quality of nuclear education and training, increases the attractiveness for engagement in the nuclear fields for students, researchers and professionals, promotes life-long learning and career development at post-graduate or equivalent level. In this way it is possible to synchronise teaching in different universities with similar in basic “core” nuclear matters and complementary advanced topics. More than 50 Italian students have received the EMSNE certificate in 10 years.

5. The doctoral programs

A qualified PhD programs is certainly one of the key-points in nuclear education at higher level, which can only be guarantied by highly-qualified research projects that require the contribution of PhD candidates. In each previously mentioned Italian university there are about 3 Ph.D. students per year who carry out nuclear engineering thesis (increasingly abroad). PhD Italian students have spent study periods at: CERN, Los Alamos, Argonne, NAKA, CEA-Cadarache, CEA-Saclay, Garching, Virginia Tech., UC Berkeley, Lisboa, Aalborg, Trondheim, PSI Zurich, Karlsruhe FZK, Areva Erlangen, Areva Paris. Some data related to the past ten years are certainly interesting and deserve some comments. For instance since the beginning of the Bologna system at Politecnico di Torino about 120 students have graduated in Nuclear engineering and it is significant that after graduation fifteen 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, often to be performed abroad.

6. Recent Politecnico di Milano and Politecnico di Torino initiative

Politecnico di Milano and Politecnico di Torino have 50 years long tradition and well recognized quality in nuclear engineering education and research. The Joint Master of Science Program in Nuclear Engineering, taking also in account that the two towns are rather near each other (about 1 hour of train), is a new initiative, launched in the academic year 2015-2016, and a unique opportunity to take advantage of the complementary know-how present in the two Universities, as well as to get access to state-of-the-art laboratories, including the research reactor TRIGA at LENA-Pavia and several other experimental and computational labs and facilities (nuclear electronics, nuclear instrumentations and measurements, radiation protection, radiochemistry, thermal-hydraulics). Moreover the foreign students can become part of a lively and stimulating international academic community, and can enjoy the Italian cultural environment. The program consists in two-year Master Science program focused on the various aspects of Nuclear engineering (fission reactor physics and engineering, fusion reactor physics and engineering, laboratory of nuclear reactor kinetics, radiation protection and radiochemistry, biomedical and industrial applications of radiation, safety of nuclear installations, thermal hydraulics, CFD etc.). The students will take courses in both universities (the first year at Politecnico di Torino and the second year at Politecnico di Milano, or vice versa), and will earn a Master’s Degree in Nuclear engineering in the university where they have chosen to be enrolled and where they will carry out the master thesis. As an example, for students enrolled by Politecnico di Torino, the Master programme (including the Nuclear engineering courses only) is shown in Table 2:

Courses held in Torino (I year)
Mandatory courses(58 ECTS)
Monte Carlo methods, safety and risk analysis (10 ECTS)
Nuclear reactor physics and transport theory (10 ECTS)
Nuclear fission plants (8 ECTS)
Radiation Protection (6 ECTS)
Biomedical and industrial applications of radiation (6 ECTS)
Computational methods for thermo-fluiddynamics (6 ECTS)
Nuclear fusion reactor physics(6 ECTS)
Nuclear fusion reactor engineering (6 ECTS)
Master thesis to be carried out in Torino at the end of II year (16 ECTS)

Courses held in Milano (II year)
Mandatory courses (25 ECTS)
Nuclear design and technology (10 ECTS)
Dynamics and control of nuclear plants (10 ECTS)
Experimental nuclear reactor kinetics (TRIGA reactor- Pavia University) (5 ECTS)
Optional courses (15 ECTS) between
Integrated deterministic and probabilistic safety analysis of nuclear power plants (5 ECTS)
Physics of nuclear materials (5 ECTS)
Plasma physics (5 ECTS)
Applied radiochemistry (5 ECTS)
Computational methods for reliability, availability and maintenance (5 ECTS)
Industrial and nuclear electronics (10 ECTS)
Radiation detection and measurement (10 ECTS)
Safety assessment of radioactive waste repositories (5 ECTS)

Table 2: Joint Master of Science Program in Nuclear Engineering for students enrolled by Politecnico di Torino

As regards the Experimental nuclear reactor kinetics course by using the TRIGA reactor, there is an agreement between the two Polytechnic Schools and the Laboratory of Applied Nuclear Energy ("LENA") of the university of Pavia which operates a 250 kW - TRIGA Mark II Research Nuclear Reactor [7]. In particular LENA offers education and training courses for students in the field of nuclear reactor physics and kinetics on the following subjects:

1. Determination of the value of the effective multiplication factor (Keff) in subcritical reactor condition;
2. Critical mass evaluation by means of the inverse multiplication factor method;
3. Approximate calibration of reactor control rods;
4. Fine calibration of reactor control rods by the method of reactor period;
5. Measurement of fuel Temperature Coefficient (prompt and stationary);
6. Measurement of the moderator void coefficient;
7. Analysis of delayed neutrons kinetics during reactor power transients and shut-down;
8. Measurement of reactor neutron fluxes.

7. Conclusions

The analysis of the Italian situation in the field of Nuclear engineering education points out to some severe problems, arising mainly from the two referenda against nuclear energy development. The consequence has been the shrinking of the specialized faculty and the difficulties connected with the reduction of public resources. To meet the needs in human resources of industry and research in the near future (especially for topics like nuclear power plant decommissioning and waste management, nuclear safety and security, nuclear fusion), industry and universities should closely collaborate and serious political decisions oriented to maintain competences and educational excellence in the field should be taken. The role of international projects and collaborations should be always more important and to preserve the Nuclear engineering and technology culture the Italian universities, like other Countries universities, should make their best efforts to attract the best students. The task is difficult, owing to the international and national contest, but the nuclear experts, involved in the Italian academic institutions, are trying to maintain as high as possible the knowledge and the cultural level of the human resources in this field, also to address important issues for Italy like decommissioning and waste management, generation IV reactors, nuclear fusion plants. The well-established CIRTEN (Consorzio Interuniversitario per la Ricerca Tecnologica Nucleare) consortium, the international collaborations, like the European Nuclear Education Network (ENEN) and the recent Politecnico di Torino and Politecnico di Milano Joint Master of Science Program in Nuclear engineering with the opportunity to take advantage of the complementary know-how present in the two Universities (including the Experimental nuclear reactor kinetics course at TRIGA reactor of the Pavia University), are worthy initiatives to improve the education and skill of the Italian nuclear engineering students.

8. References

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[5] CIRTEN, Consorzio Interuniversitario per la Ricerca Tecnologica Nucleare, www.cirten.it.

[6] ENEN, European Nuclear Education Network, www.enen-assoc.org.

[7] LENA/ TRIGA, www.unipv-lena.it.

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