COMPUTER SCIENCE - A BRIDGE BETWEEN NUCLEAR KNOWLEDGE AND PRACTICE

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Abstract.

The paper analyzes the horizon of the new information technologies, in a way that regards both parties involved in the education process: trainers and trainees. The case study refers to the Nuclear Power Plant Department within Power Engineering Faculty at University “POLITEHNICA” of Bucharest in Romania.
Attracting qualified people to nuclear field is essential for sustainable development – especially for developing countries, such as Romania. One way to accomplish this goal is to utilize the interest of the students in interconnected domains like computer based tools
The study took into account the feedback information from the students, as well as the international framework (recommendation from IAEA) in order to postulate what can be changed or improved in order to create a better learning environment.
The work revealed the fact that students have a relatively poor education related to computer programming, although there are some applications currently being studied, such as ACSL (Advanced Continuous Simulation Language). There is a need for better utilization of other general technical use programs such as Mathcad, Matlab, and specialized programs such as CANDU-9 Compact Reactor Simulator, Advanced Reactor Simulator, MMS (Modular Modelling System), MicroShield, FISPACT, designed to simulate, in an attractive and “user friendly” mode, the comportment of a nuclear power plant and for radiological assessment. This would increase the degree of understanding of the extremely complex processes that take place in such an installation.
A more practical approach is imperative in order to capture the interest of the students. Because this is not always possible, the importance of computer simulated processes is emphasized.

1. Introduction.

In the second half of the 20th century, nuclear power evolved from the research and development environment to an industry that supplies more than 16% of the world's electricity. Global environmental change and the continuing increase in global energy supply required to provide increasing populations with an improving standard of living, make the contribution from nuclear energy even more important for the next century. For nuclear power to achieve its full potential and make its needed contribution, it must be safe, economical, reliable and sustainable. To achieve this, a wide spectrum of scientific and engineering personnel is required, with a broad understanding of the technology, as well as in-depth understanding of their respective specialties.
The popularity of nuclear science and technology has decreased over the last twenty years. This fall popularity has resulted in a similar fall in new specialists entering the nuclear field. On the other hand, the majority of the predictions for the future world energy requirements point towards nuclear option being the solution for the energy problem.
Given the inherent characteristics of nuclear energy, it now appears that nuclear is the only major energy source having the capacity to provide future generations the quantities of energy needed where all requirements can be met.

Numerous studies conducted over the past five years have all come to the consistent conclusion that the nuclear pipeline cannot keep up with the needs of the nuclear industry [1]. In fact, when combining the aging work force with low matriculation rates in most nuclear engineering academic programs, a huge (and unacceptable) mismatch between needs and supply is strikingly evident. This is further exasperated by the lack of meaningful efforts to capture the knowledge of the “first nuclear era” professionals in a form that can be effectively transferred to the upcoming generation. Methods must be found to better capture the enormous body of experience already accumulated and both document it and then mentor the new nuclear engineers that do enter the work force to enable them to build upon this experience, rather than having to re-create it [1].

2. Computer Science and Nuclear Knowledge Management.

Computer-based tools are becoming standard components of training programmes. In the nuclear industry, important strides have been taken in recent years to provide a wider range of education and training services based on the use of nuclear reactor simulators [2].

To contribute to the education of scientific and engineering personnel, the IAEA sponsored the development of educational simulators that operate on personal computers and which simulate responses of a number of water-cooled nuclear power plants to operating and accident conditions. The simulators are designed to provide insight and understanding of the general design and operational characteristics of various power reactor systems [2].

The purpose is to provide university professors and engineers involved in teaching topics in nuclear energy with tools to demonstrate nuclear power plant operational response characteristics. The tools are also supplied directly to students, junior engineers, and senior engineers and scientists interested in broadening their understanding of the topic. The simulators are not intended for plant-specific purposes such as design, safety analysis, licensing or operator training, and they are not designed to link with control system components.

The nuclear industry has been losing for a long time the best and brightest students to popular fields such as computer science, bioscience and business. There is a huge need for nuclear professionals. The USA alone needs 90,000 new nuclear workers in the next 10 years – specifically 2,400 new nuclear engineers and 1,300 new health physicists [1]. This is further exasperated by the lack of meaningful efforts to capture the knowledge of "first nuclear era" professionals in a form that can be effectively transferred to the upcoming generation.

Unfortunately, there are decreasing trends in nuclear education and training vary from country to country and are closely tied to overall educational patterns in fields of science and technology. The FIG. 1. [3] is drawn from NEA’s study of 16 countries. “*Nuclear Education*

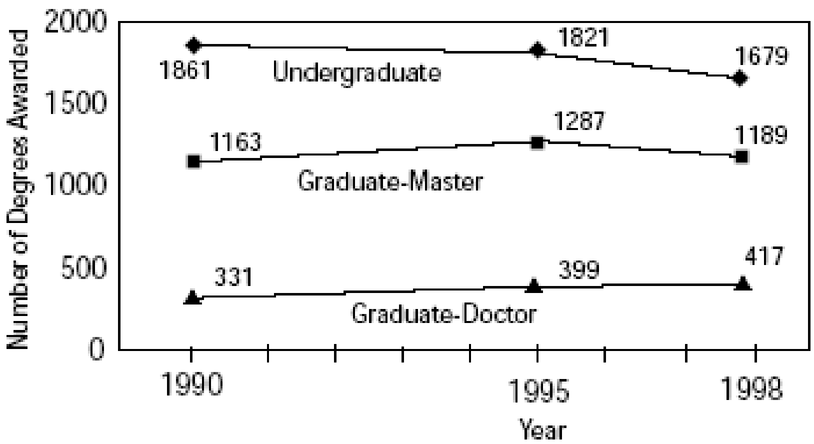

FIG. 1. *Nuclear education trends in 16 selected nuclear countries*

and Training: Cause for Concern?" in 2000, and reports at international symposia [3].
The need to understand and be in touch with today's youth – their pragmatism and perceptions of the nuclear industry as stagnant, influenced by negative publicity associated with the Chernobyl accident is highlighted. Young people no longer see the nuclear industry as "glamorous" but "old, ugly, useless and dangerous". Restoring confidence in nuclear science as a bright, prosperous career path is a prime communication challenge.
One way to accomplish this goal is to utilize the interest of the students in interconnected domains like computer based tools and "bring it under the nuclear field umbrella".
Today's students no longer have the same access to field experiments because the number of research reactors, experimental facilities and test rigs had been greatly reduced. But they may have access to state-of-the-art software. Powerful computerization in the last decade may be a part of the solution to make up for the entire loss of the resources that were originally available for nuclear technology progress.
Attracting qualified people is essential for sustainable development – especially for developing countries, such as Romania, although fundamental nuclear research has been receiving less support from government in recent years.
Government sponsored research is vital for sustainable development, because the private sector generally tends to back off from Research & Development which has long-range pay-offs.

3. Case Study at Nuclear Power Plant Department within Power Engineering Faculty at University "POLITEHNICA" of Bucharest.

Power Engineering Faculty from University "Politehnica" of Bucharest represents one of the two faculties in Romania involved in the nuclear high education (the other being The Faculty of Physics from University of Bucharest). This activity began in 1967 with the first course of "Nuclear Power Plants" and in 1970 the foundation of the Nuclear Power Plant Department was approved [4].
Since then, the department had a continuous enlargement – both in the teaching activities and scientific work. Moreover, the nuclear power plant department has been opened for the young assistant - professor generation.
According with EU requirements credits system has been introduced in our University since 1997. This system has offered students the possibility to choose between several courses for their best training [4].
There are 3 laboratories available in our department:

- Nuclear systems thermal hydraulics,
- Nuclear Power Plants – Modelling and Simulation
- Dosimetry and radiation protection.

Since 1970, in the nuclear power plant department graduated 900 students as showed in the FIG. 2. [5]. 1.

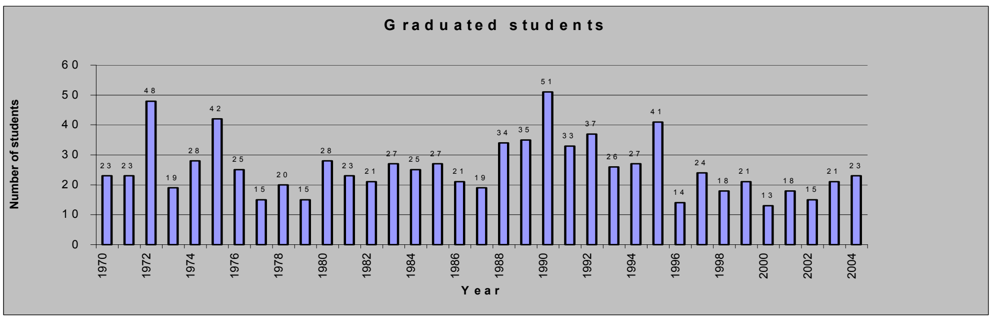

FIG. 2. *Number of graduated students in nuclear power plant department*

By observing FIG. 2. [5], it can be concluded that the downward trend in nuclear education is present in Romania as well, especially in the last decade. This situation indicates that urgent countermeasures need to be taken.

The study took into account the feedback information from the students, [8] as well as the international framework and recommendations from IAEA [3] in order to postulate what can be changed or improved in order to create a better learning environment.

Consequently the following measures were adopted:

- Create a pre-interest in the nuclear domain. Include steps such as advertisements aimed at undergraduate candidates; regular reactor visits and campus tours for students; newsletters, posters, and Web pages; summer programmes; preparation of a resource manual on nuclear energy for teachers; recruiting trips and nuclear introduction courses for freshmen; and conferences given by industry and research institutes.
- Add content to courses and activities in general engineering studies. Increase emphasis on nuclear in physics and applied physics courses; organize seminars on nuclear in parallel or in liaison with the existing curriculum using speakers external to the university; set up informational meetings on the nuclear sector, existing graduate programmes, research and thesis topics; discuss employment potential and professional activities; and call attention to the environmental benefits of nuclear energy from fission, fusion, and renewables in comparison to fossil resources.
- Change programme content in nuclear science and technology education. Include advanced courses (such as reliability and risk assessment); broaden the programme to include topics such as nuclear medicine and plasma physics; assure that the education covers the full scope of nuclear activities (fuel cycle, waste conditioning, materials behaviour); provide early real contact with hardware, experimental facilities, and industry problems; and provide interesting internships in industry and research centres.
- Increase pre-professional contacts. Encourage the participation of students in activities of the local nuclear society and its “young generation” network.
- Provide scholarships, fellowships, and traineeships. In addition to promoting several support activities (mostly technical), industry can participate financially by providing scholarships and, in several instances, has initiated new educational and training schemes. Academic societies, national research institutes, and governments also can provide financial help.
- Strengthen nuclear educational networks. Establish and promote national and international collaborations in educational and/or training programmes, e.g. summer school, specialist courses. Provide industry employees with activities that are professionally more interesting and challenging and that pay more than those in the non-nuclear sectors.
- Provide early opportunities for students and prospective students to “touch hardware”, interact with faculty and researchers, and participate in research projects.
- Provide opportunities for early undergraduates to work with faculty and other senior individuals in research situations. Use the Web and other information techniques to proactively develop more personal communication with prospective students.
- And last but not least provide increased access to computer-based tools which are becoming standard components of training and education programmes. The specific objective is to provide students with instruction and practice in development and application of nuclear power plant simulation computer codes for educational purposes. The codes operate on a PC and simulate the response, to operating and

accident conditions, of a number of reactor types. The simulators are designed to provide insight and understanding of the general design and operational characteristics of various power reactor systems.

This will provide participants with instruction and practice in development of nuclear power plant simulation computer codes using a model development system that assembles integrated codes from a selection of pre-programmed and tested sub-components. This will provide insight and understanding in the construction and assumptions of the codes that model the design and operational characteristics of various power reactor systems.

By using the simulation software in exercises implying HWR, BWR, PWR reactor simulators, in combination with the training material, students will develop an understanding of the operational response characteristics of the various reactor types.

The paper is focused on this last instance, and the question is how to accomplish this goal.

The work revealed the fact that students have a relatively low education related to computer programming, although there are some applications currently being studied, such as ACSL (Advanced Continuous Simulation Language) and MMS (Modular Modelling System) within modelling and simulation of nuclear power plants laboratory and InterRAS (International Radiological Assessment System) within dosimetry and radiation protection laboratory.

InterRAS is a set of personal computer-based tools. InterRAS contains tools to estimate the distance that urgent protective actions may be needed based on nuclear power plant conditions or release rates (ST-DOSE), to estimate early and longer term dose from field measurements of radionuclide concentrations (FM-DOSE), and to compute decay of radionuclides (DECAY). InterRAS was developed for use by personnel who conduct an independent assessment of protective actions. InterRAS Version 1.1 is based on the U.S. NRC's InterRAS Version 2.1 code (NRC94) but was modified to allow assessment of a greater range of accidents and to conform to the guidance in the IAEA Basic Safety Standard (IAEA96) [6].

ACSL (*Advanced Continuous Simulation Language*) is designed by Mitchell and Gauthier Associates (MGA) Inc. It is capable of simulating continuous dynamic systems by solving nonlinear differential equations of a mathematical model. A group of programs, called ACSL Builder was elaborated in order to make the simulation more user-friendly.

Main dynamic modelling programs from ACSL Builder are:

1. Code generating program (Translator) – For simulation program developing.
2. Execution Program (Run Time Executive) – For running simulation program

MMS is used to address the problems of model selection, application, and analysis. It consists of a set of modular modelling tools, termed the Modular Modelling System (MMS) and is being developed by the NRP Precipitation-Runoff Modelling Project. The approach being applied in developing MMS is to enable a user to selectively couple the most appropriate process algorithms from applicable models to create an "optimal" model for the desired application. Where existing algorithms are not appropriate, new algorithms can be developed and easily added to the system. This modular approach to model development and application provides a flexible method for identifying the most appropriate modelling approaches given a specific set of user needs and constraints [7].

There is a need for better utilization of other programming and general technical use programs such as C++, Mathcad, Matlab.

But most of all, there is need for specialized programs such as CANDU-9 Compact Reactor Simulator and Advanced Reactor Simulator designed to simulate, in an attractive and "user friendly" mode, the comportment of a Nuclear Power Plant, as well as MicroShield, and FISPACT for radiological assessment.

These computer based tools will be fully implemented in our laboratories. This would increase the degree of understanding of the extremely complex processes that take place in nuclear installations.

CANDU-9 Compact Reactor Simulator

This simulator, developed by Cassiopeia Technologies Inc., has 16 interactive display screens, showing overall plant systems, subsystems and control and safety systems. Each screen indicates, at the top and bottom of the display, 21 plant alarms and annunciations, simulator status, major plant events and parameters. The interaction between the user and the simulator is via a combination of monitor, mouse and display.

Control panel instrumentation and control devices, such as push-button and handswitches, are shown as stylised pictures, and are operated via special pop-up menus and dialog boxes in response to user inputs, as shown in FIG. 3. [2].

The simulator uses an object-oriented approach, and it responds to the operating conditions normally encountered in power plant operation, and to many malfunction conditions. When the plant's overview is displayed, the heat transport main loop, pressure and inventory control systems are shown as a single loop. Four steam generators are individually modelled.

Reactivity control has a separate screen that shows the limit control diagrams and the status of the three reactivity control devices that are under the control of the reactor regulating system.

There is fully dynamic interaction between all simulated systems, the unit power regulator, unit annunciation systems, and computer control of all major system functions [2].

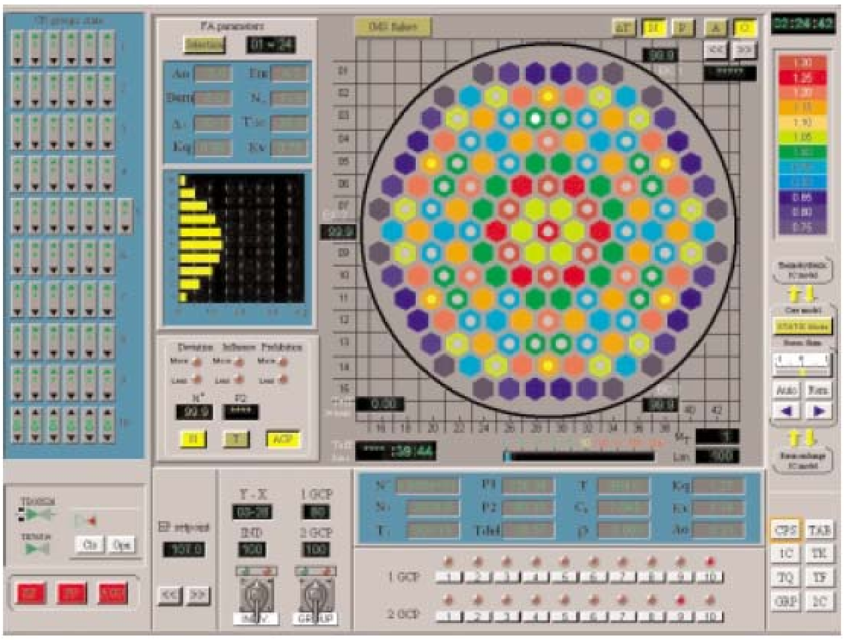

FIG. 3. *Computer display screen from the Candu-9 Compact Reactor Simulator*

Advanced Reactor Simulator.

This simulator was developed by Microsimulation Technologies in the USA and runs on a typical personal computer. It models a PWR, BWR and HWR in the 600-MWe range. For the PWR models, the simulator includes plants with vertical inverted Ubend steam generators of Western design, plants with horizontal steam generators as designed in the former Soviet Union, and a next-generation PWR with passive safety features.

The simulator operates in real or accelerated time and covers the nuclear steam supply system, containment, control systems, and safety systems.

Malfunctions and parameters can be selected to model normal and abnormal design basis conditions relevant to each reactor type. Conditions outside the design basis can also be simulated.

The display represents the controllable system as small panels with the main components shown as icons (FIG. 4. [2]). Components such as power-operated-relief-valves and safety valves of the pressurizer and the steam lines, pressurizer spray valve and heaters, main steam isolation valves, turbine bypass (steam dump) valves, feedwater valves and reactor coolant pumps are displayed. Their status is indicated by colour and can be overridden by the operator using the mouse to select objects for action (for example, push a button, turn on a pump).

Keyboard access is only required for such actions as entering malfunction values, specifying a new initial condition and entering scale values for data trends. Control rod position and motion are displayed and pipe breaks are shown with flashing sprays at the break location with the leakage flow digitally displayed.

A typical run commences with selection from a set of initial conditions corresponding to various power, flow, and time-of-life conditions. During operation, the mimic dynamically displays the plant condition and the operator can initiate malfunctions that cover all categories analyzed in the plant's safety analysis report (and beyond for some cases).

The severity, delay and ramp time of each malfunction is entered. The operator can trip the turbine or the reactor and can override the status of valves or pumps in the mimic, causing on/off status or partial failure at fractions of the full capacity. The operator can, for example, override the automatic initiation of emergency core cooling system pumps and take manual control. A set of malfunctions derived from the safety analysis report for each reactor has been prepared and can be selected, together with severity (for example, break size). Typical malfunctions include: loss of coolant; steam line break; loss of feed water; and loss of flow.

The status of the reactor protection system and safety feature actuation system is displayed. The reactor will trip automatically upon conditions exceeding any of the reactor protection system set points.

The corresponding symbol will turn red and all control rods will be inserted. Output variables can be viewed in "trend" graphs on the screen as the simulation progresses. Graphs can be printed at the end of the simulation. The operator can choose to have the calculated transient parameters written into output files for detailed post simulation analysis [2].

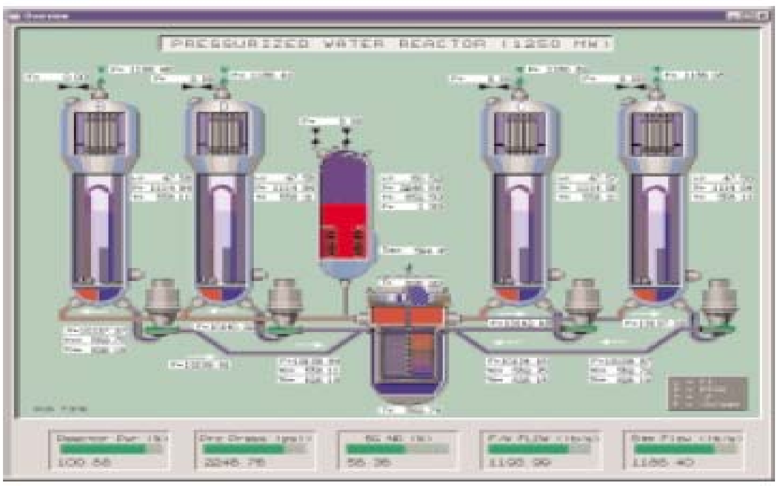

FIG. 4. C*omputer display of the reactor coolant circuit of a pressurized-water reactor used in the Advanced Reactor Demonstrator for classroom training*

MicroShield™

MicroShield™ is a compressive photon / gamma ray shielding and dose assessment program being used by more than 500 organizations. It is widely used for designing shields, estimating source strength from radiation measurements, minimizing exposure to people, and teaching shielding principles. MicroShield™ 4.21 is useful to health physicists, waste managers, and design engineers, and radiological engineers, among others. Its use requires a basic knowledge of radiation and shielding principles.

MicroShield™ specific features are [9]:

The geometry display for entry in re-scaled as dimensions is entered. Dimensional data are accepted in meters, centimeters, feet or inches. Display can be rotated in 3 - D for viewing and printing Provides the ability to design and save up to eight custom materials for any case to add to the twelve built - in materials. Sources may be created and saved and moved among cases, either as nuclides or energies, or as concentrations or totals. Several photon-grouping methods are provided including custom grouping methods.

As many as 25 energy groups (with an energy range of 15 keV to 10 MeV) may be used; input may be concentration or totals. Sensitivity of exposure rate to time, source dimension, shield thickness, or distance can be investigated. Integration conversion verification can be conducted with sensitivity to quadrate order. Decay heat/energy can be calculated. Improved flexibility for user control of units for data display and input are provided. Provides the ability to define multiple (up to six) dose points for a case for almost all geometries. The program provides the ability to operate on multiple cases simultaneously.

FISPACT

FISPACT is an inventory code that had been developed for neutron - induced activation calculations [9]. It uses external libraries of nuclear data for all relevant nuclide to calculate the number of atoms of each species at a specified time during the irradiation or after a decay following shutdown. The various species are formed either by a direct reaction on a starting material, by a series of reactions some of which can be on radioactive targets or by a decay or series of decays. The accuracy of the calculated inventor) is dependent on the quality' of the input nuclear data. FISPACT is used by preparing an Input file which uses series code words to describe the materials, the irradiation conditions, the various decay time and which of the many options (type of output and calculation parameters) are required. An Output file is always produced which contains information on each time interval in a compact but easily understandable format.

4. Conclusions.

The study took into account the feedback information from the students, as well as the international framework (recommendation from IAEA) in order to postulate what can be changed or improved in order to create a better and attractive learning environment.

Also the electric, non-electric and radioactive measurements could be performed through a modern computerized system that allows much better data acquisition, calibration, accuracy, representation, storage, interpretation and transmission of the digital information.

The students may be encouraged to exercise their basic programming skills for solving common technical problems occurred in their study projects which require simple linear iterations or more complex algorithms. If these applications are already created, the students must be permitted to use them, even thou their work become simplified.

Access to information and specialty courses is increasingly easier due to the new communications facilities, especially if the data could be found in an electronically format.

A more practical approach is imperative in order to capture the interest of the students. Because this is not always possible, the importance of computer simulated processes must be emphasized.

The nuclear industry has been losing the best students to popular fields such as computer science. There is a great need for nuclear professionals. One way to accomplish this goal is to utilize the interest of the students in interconnected domains like computer based tools and “bring it under the nuclear field umbrella”, allowing computer science to become a bridge between nuclear knowledge and nuclear practice.

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