FIRST YEAR OF GRADUATION OF THE NUCLEAR SAFEGUARDS MASTER STUDENTS

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Abstract

Twenty-five international students, with more than half being women and about half of candidates from the African continent, studied a full year and almost entirely virtually at the first ever academic master program on nuclear safeguards from October 2021 to September 2022. The program was initiated by the European Commission (EC) Directorate General for International Cooperation (DG INTPA), having recognized the lack of a complete university education in this area and building upon the expertise of the European Safeguards Research and Development Association (ESARDA). DG INTPA contracted the European Nuclear Education Network (ENEN) to set up this master program. ENEN teamed up with the Politecnico di Milano (POLIMI), Department of Energy, to develop the course in close collaboration with the EC Joint Research Centre. Three course directors and a broader scientific committee were created to develop the multidisciplinary program involving 50 experts in the teaching. By the registration deadline, 66 students had submitted an application and after an intense selection process 20 international students were selected. In addition, 5 European students enrolled, not paid by EC. The other applicants were directed to other potential capacity building initiatives (e.g. the short ESARDA course) and/or can be considered for the second year of the master that is prepared in the spring 2022.

This paper will share the experience of the program building, student selection, course implementation, return of experience of the students, teachers and organisers and report on the outcome of the program, including the thesis work and in-field working experience of the students. It will also provide an outlook for the future and some recommendations on how the course materials can be used for integration in other university programs across the globe to allow more students to be educated on specific elements of the broad field of nuclear safeguards'.

1. INTRODUCTION

In view of future nuclear developments, whether it is for nuclear newcomer countries, for those aiming to invest in Small Modular Reactors or for future deployment of generation IV nuclear reactor systems, in all cases, there is a clear request to assure that from the very early stages of each of these decisions, the 3S, safety, security and safeguards requirements are taken into account.

When taking a very simplistic but at the same time quite realistic point of view, the safety aspects will be taken care of by the reactor designer, the builder, the operator and the state in which it operates, as nobody wants to experience nuclear accidents nor any level of widespread contamination. Both of these would mean an important economical and industrial loss and thus there is a vested interest of all parties involved to assure proper respect of national and international safety regulations. An almost similar reasoning holds true for the nuclear security area as no party involved wants to be particularly vulnerable, neither to insider attacks nor to terrorist threats that would not only harm very significantly the reputation of the facility/operator/country etc but could also lead to very severe legal consequences when not having properly implemented national and/or international security legislation (e.g. the CPPNM as amended and many other requirements).

The situation is pretty different for nuclear safeguards, which is also a national and international obligation, which aims to verify that nuclear materials are not diverted from declared use and/or that no clandestine nuclear activities are performed by a state. In the first case, it is being perceived often by the operators (and even by the state) as an extra burden on the deployment of a nuclear fuel cycle, seen that the operator will know very well whether any issues could be found with the nuclear material balance of a facility, but it is certainly not, in the large majority of cases, due to deliberate nuclear material diversion, false declarations or lack of accounting and control, the latter being anyway required also to deal with the nuclear security concerns. In case it would be the intention of a state to operate clandestine nuclear activities, it can be expected to go through large efforts to try and conceal such activities and thus will experience any safeguards

inspections and questions most likely purely as a burden or nuisance. Obviously for well behaving states, it still represents a cost and commitment to respect all safeguards obligations. To paraphrase this: nuclear safeguards a priori is not the prime economic or legal concern of nuclear facility operators and/or states operating nuclear facilities even if most states worldwide signed up to the international safeguards obligations.

2. NECESSITY TO DEVELOP A NUCLEAR SAFEGUARDS MASTER PROGRAMME

In line with the above remarks, which kind of explain why the safeguards part of the 3 S might often not be given the same attention as safety and security, it was decided that a dedicated university education on nuclear safeguards was long overdue. In fact, to our knowledge, there is no full-fledged academic nuclear safeguards master programme that has been developed and/or delivered in the past, before this particular effort. Contrary to the nuclear safety (which is part of any nuclear engineering education) or also nuclear security where e.g. INSEN about 10 years ago started a major university education initiative, in the area of nuclear safeguards, we only found a bunch of short term courses (1, 2 weeks or maximum a month or so). It is clear that at the level of nuclear inspectors, e.g. at IAEA Vienna or also at regional safeguards authorities like DG ENER Euratom, detailed training courses have been developed and are regularly provided to the new inspectors to be able to properly executed their jobs. This is however not the same as a full-fledged university education, which in fact in the first instance does not aim to develop hands on skills for a nuclear operator or inspector, but instead aims to provide an academic overview, insight and knowledge in the complex area of nuclear safeguards.

Another reason why an academic education in the area of nuclear safeguards and nuclear non-proliferation was deemed long overdue, is that these areas are typically a combination of technical, legal and political factors, which are intimately connected between them, and thus require a deep understanding and insight in order to effectively contribute to the further development of national, regional and international nuclear safeguards systems. In addition, and in order to understand these multiple dimensions, a deep historical analysis is needed, such that the origin and intention but also the limitations and shortcomings of current systems are understood. It might in fact be the intense interplay and equal importance of these different elements, which was probably a major reason why no fully integrated nuclear safeguards master was developed in the past. It does indeed not belong to one faculty or one set of skills and needs to be made accessible for students with a variety of backgrounds..

3. DEVELOPMENT AND STRUCTURE OF THE MASTER PROGRAMME

The above raised issues obviously also posed a challenge for this master programme, which is why the selection process for both the teachers and the students was so important. In a first instance, a scientific board of experts was established who discussed and worked out together the learning objectives and intended outcome of all teaching materials to be developed, distributed in modules. Also the relative weight of the modules and the evaluation of which topic best to teach under which header, were part of these discussions which took several months to develop a full-fledged program. For teaching the 12 different modules of the course, a total of more than 40 experts were involved and each thematic/module was coordinated by a specialist in the area such that the different lectures in one module were consistent and comprehensive. This coordinative task definitely contributed largely to the success of the programme.

Each module consisted of a series of online contents (videos and documents, exercises, quizzes, etc), developed all ex-novo, which the students were asked to study before the webinars held in remote teaching. The webinars allowed the teachers to go more in detail and to answer questions of the students. One or more group exercises per module and an assessment/test per module concluded each of the 2 or 3 weeks blocks, according to the number of ECTs (European credit transfer system) covered. Before the final module, the students were also tasked with a 2 to 3 weeks “in-field” working period, guided by experts, under the header of “specialist laboratories” which are meant to provide the students the kick-start and key content for their thesis work they have to complete of the summer period. End of September 2022 the last module will be taught before the

graduation ceremony of the students, currently planned end of October 2022, i.e. just before the IAEA Safeguards Symposium. The Master covers 60 ECTS, and it is considered a First Level Specializing Master..

4. STUDENT SELECTION

Equally important to the programme structure was the selection process of the students. To try and attract a wide variety of student profiles and nationalities, while aiming also to bring together students, young professionals and more experienced persons, a series of publicity events were organised for the master programme, including a specific high level information event with contributions from IAEA, WNA, AFCONE, ENEN, EU-DG INTPA, etc. This was highly successful as upon closing of the inscription process, more than 60 students had applied from across the globe. Both for the efficiency and effectiveness of the teaching but also because the available funding only allowed 20 students from outside Europe to be funded, a very meticulous and detailed selection process was implemented. Each applicant to the master programme was interviewed, typically up to 30 minutes, by a panel of at least 3 persons from the organising team. They were asked about their motivation, their expectations, their current experience, their future ambitions, the compatibility of their current activities with the important commitments of the master programme etc.

In fact, quite a few applicants whose key interest was to be able to better fill out several IAEA requirements in their specific job in their country, were redirected to more operational short courses where such skills are specifically taught, rather than to enroll for a full year master programme.

The result of the selection process is illustrated in the figures below. They show the geographical (Figure 1), the gender balance (Figure 2) and the different experiences that students brought to the course (Figure 3 and 4).

It was very positive to note that almost half of the selected students came from the African continent and more than half of them are women. The mix of experience between the students constituted in fact a major element to the success of the course also because in many different sessions (both during the webinars and the group work) there were very lively interactions and discussions between the students. The fact of having made a very animated WhatsApp group between the students and the supporting staff of POLIMI, which on many occasions communicated tens of messages per day, has certainly also contributed to the creation of family feeling and strong bonding between the students which was not at all straightforward to achieve in a course which due to COVID was largely taught on-line.

The culmination of this intense networking was the series of European laboratory visits the students could do all together (and where they met the first time in person after 10 months of joint work) in June 2022. Again, the praise goes to POLIMI colleagues who dedicated a tremendous effort to pick up each student concern and find creative solutions to the most exotic problems.

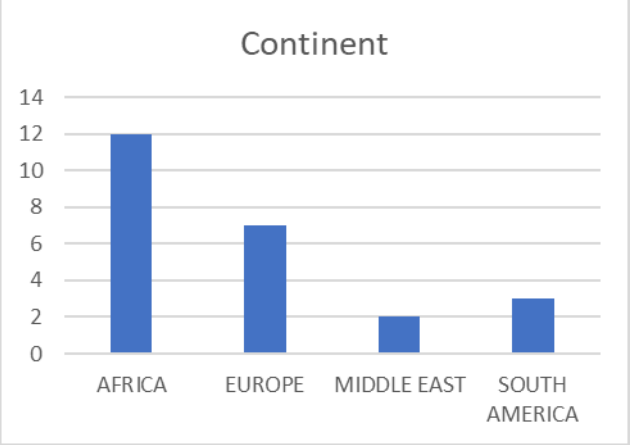

Figure 1 – Geographic distribution

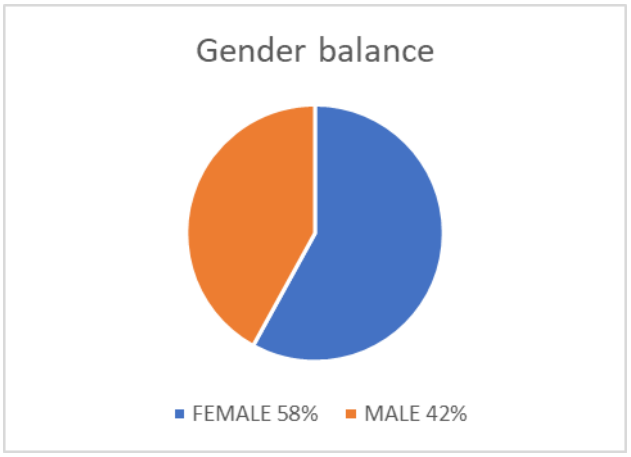

Figure 2 – Gender Balance

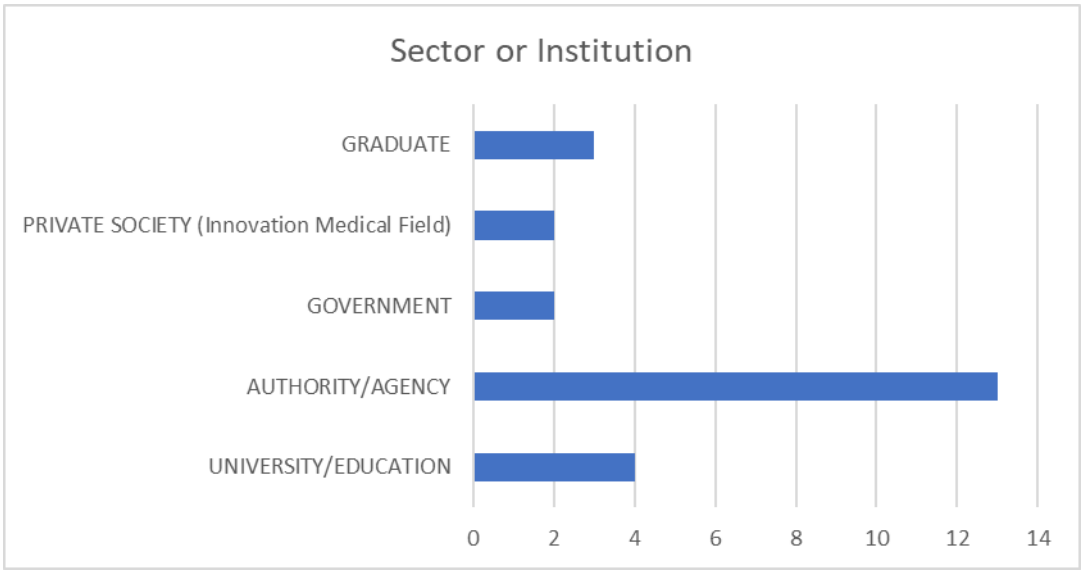

Figure 3 – Sector or institution

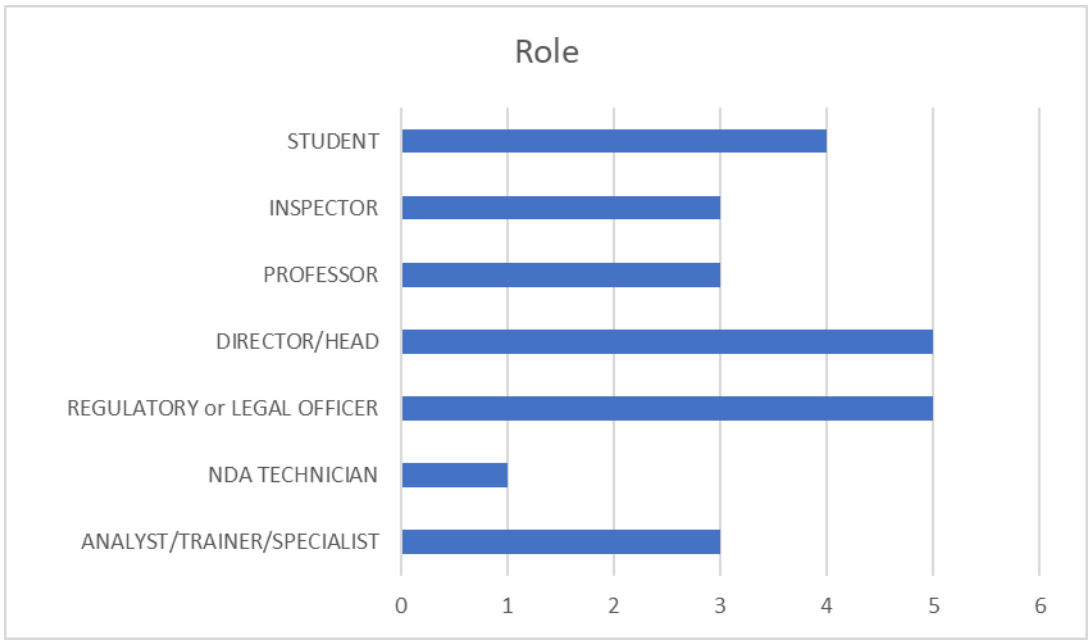

Figure 4 – Role.

5. MULTIDISCIPLINARY SAFEGUARDS

To come back shortly to the multidisciplinarity, like in all cases of national and international laws, treaties, and obligations, also the system of nuclear safeguards is necessarily a compromise between technical capabilities, legal authority and political willingness. As just one example, we can cite the fact that different countries can have quite different nuclear safeguards agreements with IAEA (e.g. small quantity protocol agreement or comprehensive safeguards agreement (CSA), or CSA plus additional protocol (AP), or voluntary offer agreement (VOA, typically for the official nuclear weapon states), or no safeguards agreement at all. To be able to grasp the complexity of this situation and to be able to contribute at national, regional and international level to "improve the situation" as good as possible (recognising that today the CSA +AP is recognised as the gold-standard for non-nuclear weapon states), the nuclear safeguards masters unversity programme aims to provide a broad, sound, academic and validated basis for the students. It is thus also hoped that the graduates of this pioneering programme will indeed find their way in the nuclear safeguards world, at home, in their continent or internationally.

6. MAJOR OUTCOME OF THE NUCLEAR SAFEGUARDS MASTER PROGRAMME

The leading team of the nuclear safeguards master programme, the ENEN, European Nuclear Educational Network, the POLIMI, Politecnico di Milano and the EU JRC, European Union Joint Research Centre, considered it would be worthwhile for the broader safeguards community during the 2022 IAEA Nuclear Safeguards Symposium, to report about the master programme, using mainly the voices of the students that followed the programme and who, upon successful completion of the advanced laboratory programmes that are currently ongoing, will be the first graduates of this programme. We therefore designed a questionnaire for the students on which we asked them to reply as transparent as possible, both to provide feedback to the organising committee and the teachers, but also to be inspirational for future potential students, seen that the programme will be repeated from February 2023 through March 2024. The questions that were asked to the students are the following:

- Why did you decide to enroll to this programme
- Did the programme reply to your expectations
- How high was the study- and workload during the year
- Did the examinations allow you to give proper record of your knowledge
- Which part of the programme was most relevant for you (as student and/or for your work)
- What was the added value of the advanced laboratories at the end of the programme
- Which recommendations do you have for the organising team for the next edition of the masters
- Would you recommend this programme to future attendees and why (e.g. networking opportunities, multidisciplinary approaches, contact with professional societies like ESARDA and INMM and also with IAEA, etc)
- How do you think you can valorise your diploma: e.g. new job, career step, enhanced international relations, etc.
- Any other remarks/suggestions you like to make

Below we like to report on the outcome of this analysis / questionnaire after which we draw some conclusions and try to formulate recommendations that can be taken on board both for the repetition of this master programme next year, but also by the universities across the globe that would like to adapt one or more of the master class modules in their university programme.

7. ANALYSIS OF THE STUDENT FEEDBACK

After a year of hard work, recognised by many students as representing a major commitment, especially when combining the study with work duties, family obligations etc., most students reported that the diploma will represent a real career step and/or will open new job opportunities for them.

Their original motivation was, in fact, first of all to broaden their knowledge and insights in nuclear safeguards and non-proliferation, seen that such integrated program does not exist elsewhere. The evaluation of individual course modules was very satisfactory across the board and the multidisciplinary modules enjoyed big enthusiasm: the overall satisfaction has been rated an average of 3,48 in the customer satisfaction questionnaire, which is a very good result, especially for a master first edition.

Some students felt most comfortable with the more technical modules like DA and NDA, which were possibly the topics that they had encountered already in the past, contrary to the content of other modules that were fully new and thus occasionally also quite challenging for them. The group work received also high praise, with the suggestion to develop more detailed mechanisms to recognise the individual contributions of the group members in the evaluation (rated an average of 3,25 in the customer satisfaction questionnaire).

Online Modules - Customer satisfaction

Scale from 1 to 4

1 = Not satisfied at all , 2 = Not satisfied, 3 = Satisfied, 4 = Very satisfied

Label	Question	Mod 1	Mod 2	Mod 3	Mod 4	Mod 5	Mod 6	Mod 7	Mod 8	Mod 9	Mod 10	Mod 11	AVERAGE
DIDACTIC	Didactic methodology	3,70	3,56	3,64	3,40	3,48	3,56	3,46	3,29	3,50	3,52	3,55	**3,51**
DIDACTIC	covered	3,91	3,80	3,80	3,68	3,16	3,88	3,29	3,58	3,67	3,65	3,77	**3,63**
DIDACTICS	Quality of materials provided (ONLINE LESSONS - Videos,	3,83	3,68	3,76	3,52	3,40	3,72	3,67	3,38	3,38	3,57	3,82	**3,60**
DIDACTICS	Quality of Webinars	NO	3,64	3,68	3,44	3,44	3,64	3,67	3,25	3,42	3,65	3,73	**3,55**
DIDACTICS	Effectiveness of Group/individual	NO	3,36	3,32	2,60	3,44	3,12	3,21	3,21	3,29	3,26	3,55	**3,25**
DIDACTICS	Achievement of learning outcomes	3,78	3,64	3,60	3,24	3,40	3,60	3,50	3,25	3,50	3,61	3,68	**3,52**
DIDACTICS	Overall satisfaction	3,70	3,56	3,60	3,16	3,28	3,56	3,50	3,25	3,42	3,65	3,64	**3,48**
LOGISTICS	platform	3,74	3,64	3,68	3,68	3,52	3,68	3,71	3,67	3,58	3,83	3,77	**3,68**
LOGISTICS	Effectiveness of administrative support and management	3,70	3,68	3,84	3,48	3,56	3,60	3,79	3,75	3,58	3,74	3,68	**3,68**
LOGISTICS	Effectiveness of communication between Organization	3,61	3,76	3,56	3,56	3,56	3,52	3,58	3,58	3,42	3,78	3,73	**3,61**
LOGISTICS	Overall satisfaction	**3,70**	**3,72**	**3,64**	**3,68**	**3,56**	**3,52**	**3,71**	**3,67**	**3,50**	**3,83**	**3,73**	**3,67**

Figure 5 - Customer Satisfaction results per Module

Occasionally students asked for some more time to accomplish the group tasks and prepare for the tests, but the overall schedule was very well appreciated.

Of course, if it would not have been because of COVID, some in person courses and e.g. basic laboratory visits in an early stage of the course would be highly welcomed such that the students get to know each other better/easier from the start.

For the advanced laboratories, which are judged extremely valuable and thus absolutely need to be maintained, there were some questions to be able to offer a broader variety of topics and thus possibly also locations. It was indeed a challenge in this first year, to define both such advanced laboratory and expert guidance opportunities for the many students and, due to the pandemic situation, the organisational issues were not trivial at all. At the end, they were very successfully implemented: the results of the thesis work that the students have to accomplish based on their advanced laboratory experience, will be evaluated by the jury early October. All students unanimously recommend this programme to future students. For the future sessions some students recommended to envisage a spread over 2 years and/or to extend the programme to 120 ECTS

(European Credit Transfer System points) so it could be followed-up by a PhD. Also a kind of job fair, with employers requiring detailed safeguards experience (like IAEA or EURATOM) was recommended at the end of the course as many students look forward to a more responsible and possibly international job in this area in the future.

8. FOLLOW-UP AND OUTLOOK

Based on the above analysis three levels of follow-up are foreseen.

The first one consists in some adaptations that will be implemented in the second edition of the course, foreseen to run from February 2023 through March 2024. A key ambition would be to adapt redesign the group work proposed in the different modules as a broad scenario activity, such that it refers to an integrated set of hypothetical situations regarding multiple countries/region with different nuclear fuel cycle activities, legal status and political system and where students could gradually learn how to apply the safeguards concepts and issues covered in the course (as the complexity of the description could grow over time, to allow the students to appreciate all steps of the construction of a safeguards system).

Secondly, it is the ambition of the organising team to be able to export a number of modules developed during this course also to other university programmes, both in Europe and abroad. For that purpose, support will be sought from existing structures in nuclear education like ENEN itself, the INSEN mechanism and the support of several regional safeguards related expert organisations like AFCONE, APSN etc.

Finally, we need to analyse carefully the market to evaluate whether future nuclear safeguards master courses (beyond 2024) would be desired and valuable, in which case it is crucial to contact DG INTPA and possibly other funding sources to allow this highly successful initiative to be continued in an integrated manner. The success will indeed determine on the long term whether the course is sustainable or whether the tremendous effort in preparing lectures, exercises, assessment activities, can indeed be valorised.

9. CONCLUSIONS

The set-up, implementation and outcome of this first of a kind nuclear safeguards master programme have been a tremendously valuable experience first of all for the students and then also for the lead directors, the scientific committee and the large set of experts teachers. This was only possible thanks to the financial support of DG INTPA which is highly appreciated. Other words of thanks go to the very strong engagement of the supporting teams of POLIMI and ENEN and the large contributions of the European Safeguards Research and Development Association ESARDA. Also, special thanks goes to the contributions of the IAEA Nuclear Safeguards Department and DG ENER Euratom Safeguards and the many individual experts that contributed to this program.