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Initiatives in Expanding Horizons of Nuclear Science in Secondary Education: The Critical Support of the IAEA Technical Cooperation Programme

Sunil Sabharwal[1,*], Jane Gerardo-Abaya[2]

[1]Division of Physical and Chemical Sciences, Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Vienna International Centre, Vienna, Austria; [2]Division for Asia and the Pacific, Department of Technical Cooperation, International Atomic Energy Agency, Vienna International Centre, Vienna, Austria

ABSTRACT

The contributions of nuclear science and technology in enhancing prosperity and quality of life all over the world and its potential to achieve many important Sustainable Developments Goals (SDGs) of the United Nations are well recognized. It also is now recognized that with fewer students getting attracted to Science, Technology, Engineering and Mathematics (STEM) in general and nuclear science and technology (NST) in particular; hence, there is a vital need to reach out to young students to provide the crucial human resources needed for these endeavours to continue in this highly specialized area. The success of a recently completed IAEA project related to introducing NST during 2012–2016 in secondary schools in the Asia-Pacific region countries encouraged the formulation of a new IAEA TC project RAS0079 entitled "Educating Secondary Students and Science Teachers on Nuclear Science and Technology" for 2018–2021, focusing on enhancing existing educational approaches through training and development opportunities both for teachers and students. The project aims at reaching a million students during the project duration while keeping the depth of learning between teacher and student. The strategy of executing the project, implementation status and its impact so far is presented in this paper.

Keywords: Education, Nuclear Science, IAEA TC Project

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Corresponding author: Sunil Sabharwal

Division of Physical and Chemical Sciences, Department of Nuclear Sciences and Applications, International Atomic Energy Agency (IAEA), Vienna International Centre, Wagramer Straße 5, 1400 Vienna, Austria
E-mail: sunsab57@gmail.com

Introduction

Nuclear science and technology (NST) contribute to almost every aspect of our day-to-day life—be it health, food, energy, environment, transport, ensuring safety and efficiency of industrial processes, management of natural resources and providing advanced materials for our needs [1–3]. Its contribution to enhance prosperity and quality of life in many areas of the world is unparalleled. For example, the introduction of nuclear based techniques has generated a diversity of experimental approaches leading to new and far- reaching insights for production of vaccines, eradication of pests, food preservation, crop improvement, and many other development-focused programmes. It also offers effective and viable solutions to address contemporary challenges faced by world as enumerated in United Nations Sustainable Development Goals (SDGs) like zero hunger, providing healthcare to people and positively impact

people's lives.

Since its inception over 60 years ago, the International Atomic Energy Agency (IAEA) has been the focal institution for developing well trained nuclear professionals with adequate skills and has played a key role in developing continued availability of qualified personnel critical for ensuring that the benefits of NST remain available for future generations. Regrettably, not only the enormous contribution of NST has largely remained unknown to a large majority in our societies, the misplaced perception and fears related to nuclear has been a major factor in overlooking the growing need for trained nuclear scientists and technologists to ensure that hitherto unforeseen and unexplored benefits of nuclear research continue to benefit future generations. The concerns and misconceptions of the public on NST need to be addressed through transparent, balanced, and focused educational activities that lead to informed understanding and enhanced knowledge. The best way to achieve this objective may be to impart this knowledge at an early stage in the school academics preferably at secondary level to excite young minds towards nuclear sciences; it offers the dual benefits of exposing all students to NST at the earliest stages of their education as well as to make a better educated society more familiar and comfortable with NST. With this in view, the IAEA implemented the Technical Cooperation programme RAS0065 during 2012–2016 that focused on introducing nuclear science and technology in secondary schools in the Asia-Pacific region. The project provided valuable experience in pilot countries and led to development of information, education and communication materials, hands-on exercises, as well as co-curricular activities to impart nuclear concepts more interestingly to the younger generation. Countries that implemented the pilot activities demonstrated the success that can be achieved by the engagement of two sectors – the nuclear sector to provide the technical and scientific expertise and the educational sector to ensure the delivery of the topics in the classroom [4]. Encouraged by the success achieved, a new IAEA TC project RAS0079 – "Educating Secondary Students and Science Teachers on Nuclear Science and Technology" was initiated in 2018 to now expand the project to all the Member States in the Asia-pacific region for the cycle 2018–2021, with a challenging task of reaching one million students [5]. The specifics of the activities implemented under the RAS0079 so far, the way forward and expected action plans are detailed in this paper.

Strategy and Implementation Approach of RAS0079

1. Strategy

While the implementation of RAS0065 targeted reaching out to students more through the co-curricular activities, the focus in this project was to design a strategy aimed at a long-term change by engaging with secondary students through teachers with appropriately designed academic as well as co-curricular activities related to general Science, Technology, Engineering and Mathematics (STEM) subjects and integrate them with NST in particular. The essential features of this strategy included:

1) Connecting nuclear establishments with academic institutions

The fast-evolving and increasing global nuclear industry needs the support of an adapted and advanced education and training system to continue getting highly skilled and trained personnel that it requires. However, in most of the Member States, the synergy between the education sector and the nuclear institution needs to be enhanced. The implementation of a pilot initiative under the IAEA TC project clearly showed the need for a close collaboration between the nuclear industry and academic establishment. It was therefore essential to establish such collaboration right from the inception of the project.

2) Developing a regional competency framework

Different Member States have diverse academic curriculum and particular subjects are taught at varying academic levels. A regional competency framework needed to be developed that could realize the requirements for teaching the essential elements of NST and for the topics to be combined with the existing academic programme of individual Member States;

3) Empowering the teachers

Making things simple is a complex task! Delivering appropriate nuclear science and technology related learning experiences in the classroom to school children needs a cross-disciplinary and collaborative approach delivered in a simplified manner. The teachers need to be equipped with the best possible chance of acquiring the requisite science content to merge with their pedagogical skills and thus enhance their confidence to teach nuclear in the classroom. The idea

is to introduce teachers to the link between the key role of nuclear science in enhancing the quality of everyday life and the simple nuclear concepts being taught in schools; as well as to provide them with innovative methods to deliver this knowledge to students through academic as well as extra-curricular approaches;

4) Enhancing NST experience in schools

Aware that the existing school curricula world over places a heavy burden on students and teachers, it was necessary to develop secondary school curriculum aids and innovative delivery methods of information about nuclear through design of simple classroom and hands-on experiments as well as use of new technological tools to impart necessary information about NST and facilitate the learning;

5) Inclusion of NST in curricula

In the long term and to reach the entire secondary school student community, appropriate mechanisms to include NST topics need to be introduced in national curricula as part of the STEM programmes.

2. Implementation approach

In the context of the implementation RAS0079 as a regional IAEA project, it was conceived that participating Member States will play a crucial role in carrying-out the activities keeping in view the limited time and resources available for the project. Therefore, a 2-stage approach was conceived—regional activities organized by the IAEA are directed at all the participating Member States while individual Member States implement their respective national activities as per their specific needs with expert assistance as needed by the IAEA.

The regional activities included (1) training course, seminars, and workshops for secondary school science teachers, (2) a train-the-trainer program to generate experts for future activities, and (3) the development and preparation of information, education and communication materials as well as hands-on/practical exercises, procurement of essential equipment.

The national activities included (1) events–seminars, workshops, and focused group discussion of teachers related to nuclear, (2) experts mission to countries to augment the national efforts to locally train other teachers, and (3) co-curricular activities to engage students in nuclear science topics.

Implementation of RAS0079

1. Forming a bridge between nuclear establishments and education sector

From the beginning of the project, the nuclear establishments in participating Member States were stimulated to formulate appropriate arrangements with the education sector to work together to exchange experience and expertise, share capabilities and resources and network between stakeholders. This initial step is most crucial for an efficient and effective implementation of the project.

2. Establishing regional competency framework

The next essential step was to formulate a regional nuclear science and technology competency framework (RCF) that could be suggested to Member States in the region. This was achieved through intense discussions at an International Workshop for Preparation of Standard Education Programmes and Modules on Nuclear Energy and Radiation Applications for Secondary Schools organized during 27–31 March 2017 at University of Tokyo, Japan. The workshop was hosted by University of Tokyo and supported by JSPS Grants in Aid for Scientific Research and RADI project operated by Japan Science Foundation (JSF). The workshop provided a clear vision of the fundamental aspects of nuclear science, modules on nuclear energy, radiation application for secondary schools and nuclear risk analysis which should form essential part of school education from Grades 6 to 12 as applicable to the Member State keeping in view their respective curriculum. The established regional nuclear science and technology competency framework was proposed to serve as reference for national educational curricula.

3. Creating the “key” resource: Competent teachers on nuclear!

It is now acknowledged that existing science teaching methods need to be augmented to raise the interest of students towards STEM subjects [6]. The Next Generation Science Standards, developed by the National Research Council in the United States has suggested new ways for teachers to interact with students by encouraging student enquiry, feeding their curiosity, and deepening their understanding of scientific concepts [7]. The need for this is even more for NST which is generally perceived by the students as a complex subject to understand. Further, many of teachers themselves have very little exposure to information related to concepts

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Table 1. The First Week Programme of the Train-the-Trainers

Technical Lectures	Technical Visits and Laboratory work
The Atomic Nucleus and Radioactivity	Visit to Nuclear Reactor and Related Facilities
Fundamental Aspects of Nuclear Applications	Visit to Accelerators and Advanced Facilities
Radiation Detection and Measurement	Visit to Nuclear Medicine Centre in Hospitals
Fission, Fusion and Nuclear Reactions	Visit to Nuclear Research Laboratories
Nuclear Sciences in Healthcare	Laboratory Experiments on Detection of Radioisotopes
Nuclear Reactors and Nuclear Energy	Half-life & Half Thickness Measurement and Their Significance
Nuclear Sciences in Agriculture	
Nuclear for Value Addition	
Radiation Processing in Food Industry	
Nuclear Sciences in Environment	
Radiation Safety and Risk Management	

and applications of nuclear sciences. It is therefore imperative to design a tailor-made programme for the science teachers in secondary schools to enrich their understanding in the nuclear related subjects and to provide them skills that place a greater emphasis on pedagogy and classroom practice to improve delivery of nuclear science education. With this in view, a 2-week training programme was formulated to train the teachers based on the suggested Regional Nuclear Science and Technology Competency Framework. The details are presented below.

1) Enhancing competency in nuclear sciences

This first week of the course is tailored to enhance participants' understanding of the fundamentals of nuclear science and technology and linking the simple concepts being taught to the many applications in the world in the day-to-day lives. The technical presentations provided in the first week can be divided into two categories: nuclear science fundamentals and applications of nuclear science. This begin with a focus on the nuclear science fundamentals in order to provide the necessary background knowledge to understand the nuclear science applications detailed later in the week. Subsequently, lectures on nuclear science fundamentals cover the basic concepts (such as the atom and its structure) to ensure that all participants have adequate knowledge before the introduction of more advanced topics. The presentations are expected to utilize a variety of audio-visual programmes and delivered in an interactive manner to excite the participants' curiosity in learning more about nuclear sciences. The hands-on experiments, demonstrations and facility visits are included to further enhance the comprehension of teachers in linking nuclear science concepts into their curricula. The details of the first week of the course are presented in Table 1.

2) Excitement in nuclear sciences teaching– The "WOW" factor

Exciting and engaging young minds in the classroom is a demanding task that requires multifaceted skills from the teacher in the classroom. This includes, besides a wide range of subject knowledge, the soft skills to successfully accomplish the task of the classroom teaching [8]. The evolving role of soft skills in education is now getting recognized to enhance the talents, and attitudes of the students. Extra-curricular and co-curricular activities also play a significant role in the development of students during the school life and help in enhancing their learning process, allowing them to appreciate topics beyond the curriculum subjects. Therefore, after providing the necessary technical information in the first week of the course, the second week of the training course is focused on the curriculum development lectures which include presentations on soft skills, lesson plan project, extra-curricular activities, outreach, and careers in NST. In addition to that, the second week of the course includes laboratory experiments, the development of a lesson plan and class simulation, as well as the presentation of national action plans. The week activities are conducted by a separate group of experts comprising of the experienced educators as well as experts in the outreach activities. The participants are exposed by the teachers to a variety of activities such as the Marshmallow Challenge, thinking maps, puzzles, diamante poetry and class presentation in areas related to the subjects of NST. During these sessions, appropriate technical advice/suggestions are provided to ensure that the technical content being presented/discussed is accurate and correct. Details of planning the outreach and extra-curricular activities and possible ways of adapting such activities are shared with the participants. A brief description of the second week schedule is presented in Table 2.

Table 2. The Second Week Schedule of the Train-the-Trainers

Activities Related to Soft Skills	Co-curricular activities
Role of Extracurricular Activities in Teaching NST	Class Observation Topic: Detecting Radiation
Planning Extracurricular Activities in Enhancing Nuclear Science Activities	Class Observation Topic: Cloud Chamber
Developing Soft Skills for Teaching Nuclear Science and Technology	Teachers Demonstration on Extracurricular Activities
Developing Lesson Plans, Accumulating Resources & Assessment Tools	Teachers Presentation on Selected Topic
Planning Outreach Activities in Enhancing Nuclear Science Activities	
Adapting Academic Activities into the Curriculum for Specific Needs	
Adapting Extracurricular Activities into the Curriculum for Specific Needs	
Careers and Opportunities in Nuclear Science and Technology	

Table 3. List of Training Courses Conducted and Envisaged

S.No.	Date	Institution	Number of participants
1	16–27 April 2018	Polytechnic Institute of Nuclear Technology, National Nuclear Energy Agency of Indonesia (BATAN), Yogyakarta, Indonesia	27
2	20–31 August 2018	Argonne National Laboratory, Argonne, Illinois, USA	30
3	20 Feb–1 March 2019	The University of Tokyo, Japan	17
4	17–28 June 2019	Philippines Nuclear Research Institute (PNRI), Quezon City, Philippines	22
5	1–12 July 2019	Nuclear Malaysia, Kuala Lumpur, Malaysia	19
6	14–25 October 2019 (Planned)	Argonne National Laboratory, Argonne, Illinois, USA	22
7	9–20 December 2019	ANSTO, Sydney, Australia	23 nominations received

At the end of the training workshop, the participants are expected to have developed a lesson exemplar in nuclear science and technology as well as an action plan outlining the different activities that the participant plans to do once he/she returns to his/her home country. The lesson exemplars are demonstrated by the participants in the group and evaluated by the IAEA panel of experts. The action plans to propagate the knowledge and experience upon return to the home countries by individual participants are likewise reviewed by a panel of experts.

3) The multiplier effect

The responsibility for the introduction of NST at the national level rests with the individual Member State and for meeting this objective, the teachers trained through the regional training courses are expected to train the fellow teachers through national level training courses. This important and crucial activity is expected to provide the necessary multiplier effect through which a much larger number of teachers could be reached under the programme. The IAEA supports this activity by providing necessary experts to augment the national resources.

4) Train-the-trainer workshops

It was clearly envisaged that the scope and quantum of activities needed to be implemented at regional and national levels over the 4-year project duration will need a large pool of trained science teachers and/or communicators. It is therefore necessary to intensively train teachers or scientific researchers from within the region so that they can be entrusted with the task of providing expert services in the planned activities. To achieve this objective, an intensive course has been specifically designed for science teachers and researchers to provide the essential information related to the basics of nuclear science, applications of nuclear sciences, and risk management of nuclear technology. This train-the-trainer workshop is expected to be of great value to educators for developing a deeper understanding of nuclear science and to convey this through innovative approaches in the region.

Project Implementation Status

1. Regional IAEA training courses for teachers

Since the beginning of the project in 2018, IAEA has trained 120 teachers through 5 regional training courses for teachers, and two more are envisaged during October 2019 and December 2019 at Argonne National Laboratory and Australian Nuclear Science and Technology Organisation (ANSTO), respectively. The details of the training courses are presented in Table 3. All the training courses have been extremely well received by the participants and all lessons-learned during

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all the programmes have been comprehensively compiled and carefully analysed for planning of future workshops to ensure that the quality of the subsequent workshops grows every time.

2. National activities

The participating Member States have made significant progress in implementing the project by participation in regional activities as well as organizing national activities to reach out to teachers and students. This has been facilitated by the linkage formed between the nuclear institution and the academe in many Member States. For example, the Ministry of Education in Sri Lanka, together with IAEA, Polytechnic Institute of Nuclear Technology, BATAN, Indonesia and Sri Lanka Atomic Energy Board (SLAEB) organized a group Scientific Visit (SV) for 20 secondary school teachers for enhancing their capabilities to teach NST in more effective and engaging manner. In the Philippines, a memorandum of understanding has been signed between the Philippine Nuclear Research Institute and the education sectors in Philippines which include the Department of Education and the Philippine Science High School System as well as the Department of Science and Technology (DOST)-Science Education Institute. The program hopes to reach science teachers in the seventeen regions of the Philippines. For 2018, nine regions have already introduced into the program. Similar initiatives have been undertaken in Malaysia, Indonesia and Thailand. National level training courses supported by IAEA experts have been organized in Jordan, Malaysia, Mongolia, Oman, Sri Lanka and Thailand. The participating Member States have successfully adapted programmes such as POWERSET, Seminars/Workshops for Teachers & Students in Secondary Schools (SWTSSS), and Science on Saturdays (SOS) as per their needs besides developing their own programmes like *Nuclear Goes to School*. These activities have enhanced the involvement of students from various disciplines and have provided exposure to various aspects of nuclear science and technology.

3. Train-the-trainers

The first of the series of "Train the Trainers" workshop was held on May 20–24, 2019 hosted by the Philippine Government through the Philippine Nuclear Research Institute and in partnership with the Philippine's Department of Education, Philippine Science High School and DOST-Science Education Institute. The 12 participants of the workshop from 7 Member States in the region were science teachers, information officers and scientists/researchers in atomic institutes who have been a participant in earlier trainings/workshops arranged under RAS0065 or RAS0079. This workshop has led to creation of experts who will now be support future national or regional courses as resource persons besides contributing to similar activities in their own country.

Impact of RAS0079: From Constrictions to Competence!

The activities conducted under the project and their impact so far was evaluated 10 months after launch during a meeting in December 2018. The discussions at the meeting showed that the project implementation has been successful so far with the following major achievements:

- Collaboration between Nuclear Agency and Ministry of Education has been established for the nuclear education purpose in many Member States. This partnership, for example as in Philippines, is leading into a structured and organized program involving the stakeholders through strategic partnerships including engagement with teacher's training institution, wider awareness program and revision of related syllabus. Incorporation of NST related subjects in the school curricula will ensure that all the secondary students in the Member State will be received appropriate information related to nuclear;
- Under the IAEA Regional Training Programmes, about 120 teachers were trained, while the National Programmes conducted by the Member States until December 2018 were able train 1,350 teachers clearly reflecting the multiplier effect. More importantly is the fact that the training course succeeded in its objective of providing relevant and correct information on nuclear to the teachers and in alleviating their perceived fears about nuclear science. This is leading to highly motivated teachers eager to teach NST in schools;
- The enthusiasm of the Member States in implementing the project was apparent as over 171,137 students have been reached within the first 10 months of the project of which 96,505 were directly reached through classroom activities while 74,632 students interacted through national extracurricular activities in the Member States;
- An important spin-off of the project in some Member States has been the development of low-cost equipment which can be handled by students as an essential aid in

developing scientific learning, and in cultivating interest in the field. These include locally fabricated cloud chamber experiments with indigenous low-cost materials and simple radiation detection instruments suitable for students. The participants in the training courses are made familiar with assembling of these instruments, thus offering the hands-on experience to make science laboratory equipment. The ability to make such aids are some of the valuable skills that will help in mentoring the next generation of nuclear scientists, engineers and technologists;

- Lesson-Planning are valuable tools that are indispensable in good teaching as these provides for adequate lesson summaries, ensures a definite assignment for class, and ensures availability of materials for lesson. The aim of incorporating NST in school curriculum cannot be achieved without developing such resources. An important output of the training courses are lesson plans on subjects related to NST based on the classroom experience by the teachers participating in the training courses. The lesson plans will grow as more teachers continue to share their work, and will be compiled in a compendium as an extremely valuable resource and reference;
- Teaching in mother-tongue has a great importance in the field of education and has a prominent place in the school curriculum. Recognizing this, the teachers trained through RAS0065 and RAS0079 have initiated and developed resources in their national languages related to subjects of NST. This probably is one of first attempts to develop resources related to NST which will considerably impact the outreach of NST.

Conclusions

The IAEA initiatives over the years have succeeded in generating a new wave of enthusiasm and excitement in the teaching and students' community and brought a visibility to nuclear science in participating Member States. The activities under the project focusing on academic and extracurricular activities have proved to be comprehensive, simple and effective in generating interest for nuclear related topics. The project implementation has significantly strengthened the commitment of the participating Member States to adapt and expand the initiatives by incorporating nuclear in their school curriculum. The synergy between Member States and the IAEA in implementing planned new initiatives under the project RAS0079 during 2020–2021 will help ensure that the goal of enriching nearly a million students with NST are successfully met.

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Disclaimer

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